

CONCRETE

In Highway
Construction



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THE ATLAS PORTLAND CEMENT CO.
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CONCRETE IN HIGHWAY CONSTRUCTION

A Text-Book for Highway
Engineers and Supervisors

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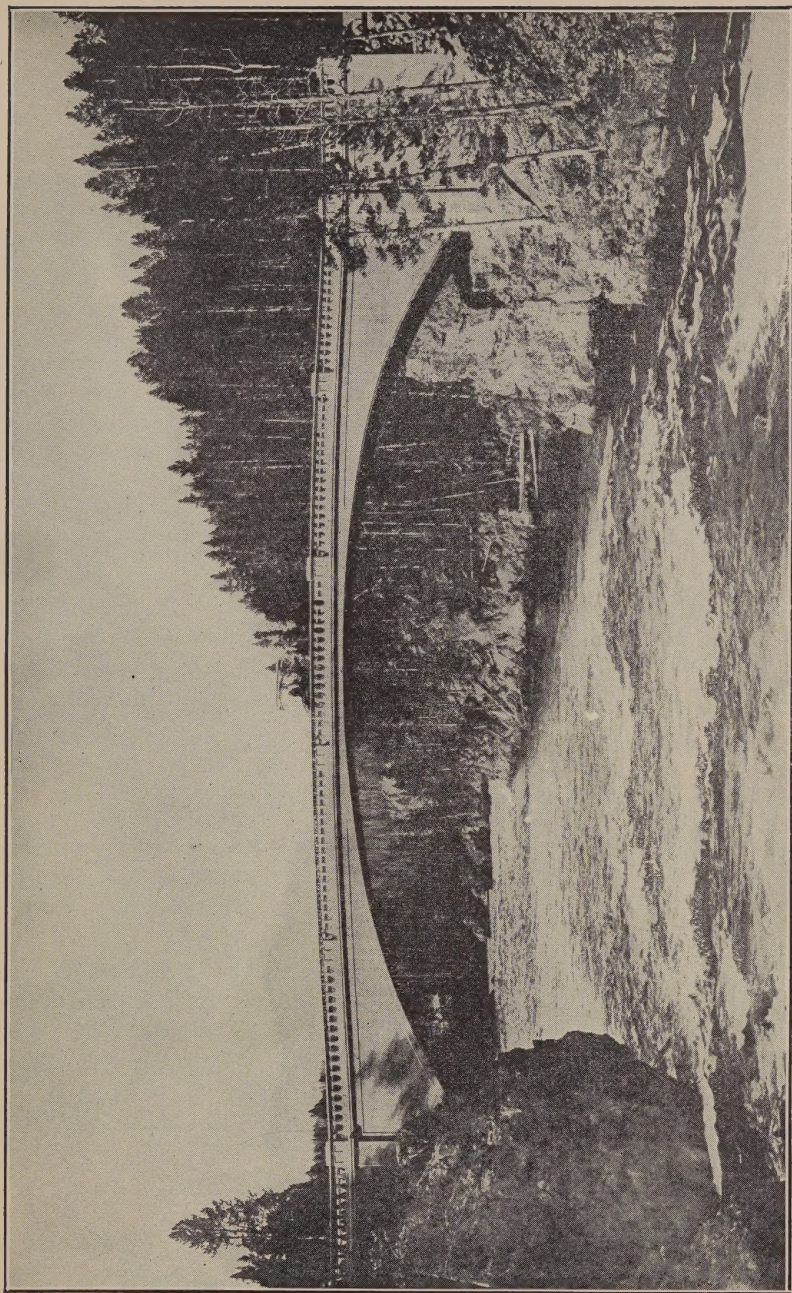
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CONCRETE BRIDGE OVER THE YELLOWSTONE RIVER, YELLOWSTONE NATIONAL PARK

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FOREWORD.

The development of manufacture and of agriculture, which require proper transportation facilities not only on the railroads but to the points of shipment and distribution, has stimulated a widespread interest and called national attention to the necessity for better pavements and for highway constructions of a more permanent and durable character.

This demand, as well as the necessity for reducing the expense of repairs incident to automobile traffic, has brought to the forefront the use of concrete to produce permanent construction, not only for sidewalks and pavements, but for highway structures, such as bridges, retaining walls, culverts, and the many smaller details, the repairs to which are continually vexing the City and Town Engineer and the Highway Commissioner.

The purpose of the present volume, then, is to present to those in charge of street and highway construction and maintenance, examples of work which have been satisfactorily performed, and, further, to give drawings and designs made especially for The "ATLAS" Portland Cement Company, either as reproductions of existing structures, from drawings and photographs kindly furnished by the local authorities, or as original designs prepared by expert engineers at the request of the "ATLAS" Portland Cement Company.

The most important matter of sidewalk construction is taken up in considerable detail, while concrete street pavement construction has been thoroughly investigated, and recommendations made of methods which have produced durable and satisfactory results. Numerous examples and suggestions are given in the line of bridge design and construction, both for arches and flat bridges; sewers, culverts and retaining walls are quite thoroughly treated; and such minor structures as drains, brook linings, fences and posts, are illustrated and described.

Although the information in this little volume is more valuable and in much greater detail than is customarily presented by manufacturing companies, the position of The "ATLAS" Portland Cement Company as the leading cement manufacturers in the world has led them to present data which will tend not only toward an increasing use of cement but toward a use of cement according to the best, safest and most economical practice.

This present volume together with the other books of The "ATLAS" Portland Cement Company, namely, "Concrete Construction About the Home and on the Farm"; "Concrete Country Residences"; "Reinforced Concrete in Factory Construction," and "Concrete in Railroad Construction," covers a wide range in the use of concrete.

THE ATLAS PORTLAND CEMENT COMPANY.

New York, June, 1909.

CHAPTER I.

CONCRETE.

During the year 1907 the State Highway Commission of Massachusetts spent \$468,000 in the construction of new roads and \$106,000 for repairs and maintenance of roads in its charge. The State Highway Department of Pennsylvania expended \$3,187,000 in the construction of new roads up to January 1, 1908, and in the report of this department for 1907 the sum of \$29,225,000 is given as the total cost of roads completed, under contract and to be built. Other States are similarly engaged in building new roads, and improving old ones so that the movement for better roads and streets is almost universal. Such enormous costs of construction and maintenance show the necessity for the selection of materials which, in the long run, are the cheapest and most economical.

Concrete is playing a large part in this construction and re-construction, not so much in the roadbed proper, although as is shown in the pages which follow, concrete street pavements are well adapted to certain conditions, but especially for the various structures which are necessarily incidental to road building.

This class of work includes not only such structures as are necessary in first-class streets or highways, such as culverts, bridges and retaining walls, but also in the roadway itself, either as a foundation for a stone, brick or asphalt surface, or as a complete pavement including foundations and wearing surfaces.

For smaller uses concrete has a still wider field. For sidewalks, curbs and gutters its use is becoming quite universal, while as a material for drain tiles, lamp posts of various styles, hitching posts, fence posts, and many other highway appurtenances, its value is fast being recognized, as is shown by the enormous increase in its use for such purposes. As a material for building park structures, such as bridges, buildings, drinking fountains, and seats, concrete is well suited because of its cheapness, durability, and the ease with which it is molded into artistic designs.

In the larger structures such as bridges and retaining walls, especially where steel reinforcement is necessary to give the required strength, a proper design with good working drawings showing the dimensions and the location of the steel is of the utmost importance, and where the structure is of appre-

cialable size a competent engineer familiar with the principles of design and with practical construction in concrete should be employed to prepare plans and specifications, and to superintend the construction. On the other hand, many of the minor details can be built with but little engineering experience, provided directions given by competent authorities are carefully followed, and good judgment is used in the selection of the materials and in the work of construction.

The principal requisites of a material used in building various structures forming the necessary parts of a well-constructed, modern highway are cheapness and durability. If the first cost of the structure is to be small the materials used in its construction must be cheap and must be easily placed in position by ordinary workmen, and if the cost of maintenance is not to be excessive the materials used must possess qualities that will enable them to withstand the elements successfully. Wood, steel, stone, and concrete are in general the principal materials used in the construction of highway appurtenances such as bridges, culverts, sidewalks, curbs, and gutters. Of these four materials wood is usually the cheapest in first cost for small structures and is the least durable of all. The cost of maintenance of ordinary wooden bridges is so great and the life is so short that wood is really no longer considered seriously as a material for first-class construction, especially in those localities where lumber is scarce. Stone is generally a durable material of construction, but its first cost, and in many places its scarcity, tend to limit its use for highway purposes. It is also difficult and expensive to shape stone into desired forms which in many cases are required to secure the best results. The importance of steel in the construction of highway bridges of long spans is well understood, but its cost and the constant heavy maintenance charges, or its rapid deterioration if not properly maintained, have caused builders of bridges to seek some other material which is lower in first cost and which will not require constant painting. Clearly, concrete, or concrete with steel imbedded in it to reinforce it, is the material above all others that combines the advantages of cheapness and durability. Concrete can be made at small expense in practically any locality; can be molded in any desired shape or size; requires no maintenance, and can be placed in position with very little skilled labor.

In making concrete the cement, sand, and stone or gravel should be carefully chosen, thoroughly mixed, and properly laid. If these precautions are taken the mass will begin to stiffen in an hour or so after being laid and will continue to harden until in about one month's time the mass becomes a hard compact stone.

CEMENT.

Portland cement of first-class reputation should be used to obtain the greatest uniformity, reliability and the highest strength. If the work is small and unimportant and a brand of cement of first-class reputation is purchased from a reliable dealer no testing is necessary, but for important structures the cement should be tested and should meet the requirements of the American Society for Testing Materials.* If it is impracticable to make these complete tests, specimens may be made to see if the cement sets up properly. The following, also, is a simple test for determining the soundness of the cement:

A sound cement will not crumble when placed in the work and a test for soundness is therefore of considerable importance. Oftentimes no other test need be made. Mix, by kneading $1\frac{1}{2}$ minutes, one cupful of Portland cement with enough water to form a paste having a consistency like that of ordinary putty. Place part of this paste on each of 3 pieces of glass about 4 inches square so as to make a pat about 3 inches in diameter and $\frac{1}{2}$ inch thick at the center tapering down to a thin edge. Leave these 3 pats under a damp cloth arranged so that it will not touch them for 24 hours. Then place one pat in air at an ordinary temperature for 28 days, a second pat in water for 28 days, and the third pat in a tightly closed vessel over boiling water for 5 hours. If the cement is of good quality the pats will show no radial cracks and they will not crumble. If the time is limited and the pat placed in steam shows no signs of crumbling the cement may be accepted on this steam test alone.

Portland cement is manufactured from a mixture of two materials, one of them a rock like limestone or a softer material like chalk which is nearly pure lime, and another material like shale, which is a hardened clay, or else clay itself. In other words, there must be one material which is largely lime and another material which is largely clay, and these two must be mixed in very exact proportions determined by chemical tests, the proportions of the two being changed every few hours to allow for the variation in the chemical composition of the materials.

"ATLAS" Portland Cement is made by quarrying each of these materials, crushing them separately, mixing them in the exact proportions, and grinding them to a very fine powder. This powder is fed into long rotary kilns, which are iron tubes about 5 or 6 feet in diameter lined with fire brick and over 100 feet long. Powdered coal is also fed into the kilns and burned at a temperature of about 3,000 deg. Fahr., a temperature higher than that needed to melt iron to a liquid and there is formed what is called cement clinker, a kind of dark porous stone which looks almost exactly like lava.

*These may be obtained by addressing The Atlas Portland Cement Company.

After leaving the kiln, the clinker is cooled, crushed, and ground again to a still finer powder, so fine, in fact, that most of the particles are less than $1/200$ of an inch in size, and this grinding produces the light gray-colored powder characteristic of "ATLAS" Portland Cement.

It is now placed in storage tanks or stock houses where it should remain for a while to season before it is put into bags or barrels and shipped. The barrels weigh 400 pounds gross, or 376 pounds net. When shipped in bags the weight is 94 pounds per bag, four bags being equal to one barrel.

At the "ATLAS" plants from the time the rock is taken from the quarry until it is packed in barrels or bags all of the work is done by machinery, and a thorough chemical mixture takes place regulated by the experienced chemists in charge of the work.

STORING CEMENT.

Cement should come packed in barrels or in stout cloth or canvas bags and should be stored in a dry place, preferably a house or shed until used, or if no such storage house is available the cement should be placed on a wooden platform raised at least 6 inches above the ground and should be covered so as to exclude water. When used the cement should be free from lumps.

SAND OR FINE AGGREGATE.

The term aggregate includes the stone and sand in concrete and may be classified as fine and coarse. The fine aggregate may be sand or crushed stone or gravel screenings which will pass when dry a screen having $1/4$ inch diameter holes. If sand is used it should be clean and coarse, or a mixture of coarse and fine grains with the coarse grains predominating. It should be free from loam, clay, mica, sticks, fine roots, or other impurities. Sand should be coarse, that is, it should have a considerable portion of its grains measuring $1/32$ to $1/8$ inch in diameter and should the grains run up to $1/4$ inch the strength of the mortar is increased.

Vegetable loam is frequently very injurious to concrete and great care should be taken in selecting and excavating to see that the sand does not contain any vegetable matter. For all important structures the sand should be tested in a laboratory as described in the following paragraphs:

"Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should show a tensile strength of at least 70 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand. To avoid the removal of any coating on the grains which may affect the strength, bank sands should not be dried before being made into mortar but should contain natural mois-

ture. The percentage of moisture may be determined upon a separate sample for correcting weight of the sand. From 10 to 40 per cent more water may be required in mixing bank or artificial sands than for standard Ottawa sand to produce the same consistency.”*

“The relative strength of mortars from different sands is largely affected by the size of the grains. A coarse sand gives a stronger mortar than a fine one, and generally a gradation of grains from fine to coarse is advantageous. If a sand is so fine that more than 10 per cent of the total dry weight passes a No. 100 sieve, that is, a sieve having 100 meshes to the linear inch, or if more than 35 per cent of the total dry weight passes a sieve having 50 meshes per linear inch, it should be rejected or used with a large excess of cement.”*

Crushed stone or gravel screenings, when used in place of sand, should pass when dry a screen having $\frac{1}{4}$ -inch diameter holes or a screen having 4 meshes to the linear inch and if free from impurities may be substituted for a part or the whole of the sand in such proportions as to give a dense mixture.

COARSE AGGREGATE

Gravel or crushed stone of a hard and durable quality make up the coarse aggregate for concrete. The best materials are trap rock, hard limestone, granite, or conglomerate of size retained on a screen having $\frac{1}{4}$ -inch diameter holes.

Aggregates containing soft, flat, or elongated particles should be excluded from important structures. Stone which breaks into cubical or similar angular forms is much preferable in any case to that which breaks into flat layers because it gives a stronger concrete and one which is more readily placed. Graded sizes of particles, that is, particles varying from small to large sizes, are generally advantageous. Where concrete is used in mass, the crushed stone or gravel may range in size from $\frac{1}{4}$ inch to that which passes through a 3-inch ring. For reinforced concrete, the particles must be small enough to flow into place around and between the steel bars and into all corners of the forms. For this a maximum size of 1 inch (that is, the largest particle small enough to go through a 1-inch ring), or in other cases a $\frac{3}{4}$ -inch or $\frac{1}{2}$ -inch must be used. The material passing the $\frac{1}{4}$ -inch screen may be used as a part of the sand.

If gravel is used instead of crushed stone, it should be of a size to be easily handled and easily placed around the steel if there is steel reinforcement and it should be clean and free from vegetable or other deleterious matter. As in the case of crushed stone, the material below $\frac{1}{4}$ inch in size should be screened out to be used as sand. Sand and gravel are rarely found mixed in the proper

*Report of Committee on Reinforced Concrete, 1909, National Association of Cement Users.

proportions in the natural bank, and it is cheaper to screen and remix them in the correct proportions than to use the richer mixture necessary with unscreened material.

Pebbles of graded sizes with the larger sizes predominating are preferable to pebbles of a uniform size because they are more readily mixed and placed.

For important structures and for structures where there will be considerable wear on the concrete, the materials should be carefully selected, but for unimportant structures it is usually sufficient to make two small blocks of concrete, say 6-inch cubes, and place one of these cubes out-of-doors in air for 7 days and the other in a fairly warm room.

The specimen placed in the warm room should be hard enough at the end of 24 hours to bear pressure from the thumb without indentation and it also should whiten out to some extent during this time. The specimen placed out-of-doors should be hard enough to remove from the mold at the end of 24 hours in ordinary mild weather or 48 hours in cold damp weather. At the end of a week test both blocks by hitting them with a hammer. If the hammer does not dent them under light blows such as would be used in driving tacks and the blocks sound hard and are not broken under these blows the sand as a general rule can be used.

WATER.

Water used in mixing concrete should be free from oil, acids, alkalies, or vegetable matter.

PROPORTIONS OF MATERIALS.

The following paragraphs relating to the proper proportions of materials for making concrete are taken from "Concrete Construction About the Home and on the Farm": *

"Concrete is composed of a certain amount or proportion of cement, a larger amount of sand, and a still larger amount of stone. The fixing of the quantities of each of these materials is called proportioning. The proportions for a mix of concrete if given, for instance, as one part of cement to two parts of sand to four parts of stone or gravel, are written 1:2:4, and this means that one cubic foot of packed cement is to be mixed with two cubic feet of sand and with four cubic feet of loose stone.

"For ordinary work, use twice as much coarse aggregate (that is, gravel or stone) as fine aggregate (that is, sand).

"If gravel from a natural bank is used without screening, use the same proportions called for of the coarse aggregate; that is, if the specifications call for proportions of 1:2:4, as given above, use for unscreened gravel (provided it

*Published by The Atlas Portland Cement Company, from whom it can be obtained by making application for same.

contains quite a large quantity of stone) one part cement to four parts unscreened gravel.

"If when placing concrete with the proportions specified, a wall shows many voids or pockets of stone, use a little more sand and a little less stone than called for. If on the other hand, when placing, a lot of mortar rises to the top, use less sand and more stone for the next batch.

"In calculating the amount of each of the materials to use for any piece of work, do not make the mistake so often made by the inexperienced that one barrel of cement, two barrels of sand, and four barrels of stone, will make seven barrels of concrete. As previously stated, the sand fills in the voids between the stones, while the cement fills the voids between the grains of sand, and therefore the total quantity of concrete will be slightly in excess of the original quantity of stone."

The unit of measure is the barrel, which should be taken as containing 3.8 cubic feet. Four bags containing 94 pounds of cement each are equivalent to one barrel. Sand and stone or gravel should be measured separately as loosely thrown into the measuring receptacle.

The following quotation from "Concrete, Plain and Reinforced"* by the well-known authorities, Taylor and Thompson, is printed as a guide to those who wish to build any concrete structure for which specific instructions are not given in the following pages:

"As a rough guide to the selection of materials for various classes of work, we may take four proportions which differ from each other simply in the relative quantity of cement":

(a) A Rich Mixture for columns and other structural parts subjected to high stresses or requiring exceptional water tightness: Proportions—1:1½:3; that is, one barrel (4 bags) packed Portland cement to 1½ barrels (5.7 cubic feet) loose sand to 3 barrels (11.4 cubic feet) loose gravel or broken stone.

(b) A Standard Mixture for reinforced floors, beams and columns, for reinforced engine or machine foundations subject to vibrations, for tanks, sewers, conduits, and other water-tight work: Proportions—1:2:4; that is, one barrel (4 bags) packed Portland cement to 2 barrels (7.6 cubic feet) loose sand to 4 barrels (15.2 cubic feet) loose gravel or broken stone.

(c) A Medium Mixture for ordinary machine foundations, retaining walls, abutments, piers, thin foundation walls, building walls, ordinary floors, sidewalks, and sewers with heavy walls: Proportions—1:2½:5; that is, one barrel (4 bags) packed Portland cement to 2½ barrels (9.5 cubic feet) loose sand to 5 barrels (19 cubic feet) loose gravel or broken stone.

(d) A Lean Mixture for unimportant work in masses, for heavy walls, for large foundations supporting a stationary load, and for backing for stone masonry: Proportions—1:3:6; that is, one barrel (4 bags) packed Portland cement to 3 barrels (11.4 cubic feet) loose sand to 6 barrels (22.8 cubic feet) loose gravel or broken stone.

*See reference, footnote, page 18.

QUANTITIES OF MATERIALS IN CONCRETE.

In estimating the quantities of cement, sand, and broken stone or gravel in a given volume of concrete or in estimating the volume of mortar or concrete which can be made from one barrel of cement the three accompanying tables will be found useful. The values given in the tables are computed from results of actual experiments and have been checked with concrete laid in large masses.

VOLUME OF CONCRETE MADE FROM ONE BARREL OF PORTLAND CEMENT*

Based on a Barrel of 3.8 Cubic Feet

Proportions by Parts			Proportions by Volume			Volume of Mortar in Terms of Percentage of Volume of Stone	Average Volume of Rammed Concrete Made From One Barrel of Cement		
							Percentages of Voids in Broken Stone or Gravel		
Cem't	Sand	Stone	Cem't	Sand	Stone		50%†	45%‡	40%§
			bb'l.	cu. ft.	cu. ft.	per cent.	cu. ft.	cu. ft.	cu. ft.
1	1	2	1	3.8	7.6	75	9.5	9.9	10.3
1	1	3	1	3.8	11.4	51	11.5	12.2	12.8
1	1½	3	1	5.7	11.4	64	12.9	13.5	14.1
1	1½	3½	1	5.7	13.3	55	13.9	14.6	15.4
1	2	3	1	7.6	11.4	75	14.3	14.9	15.5
1	2	4	1	7.6	15.2	57	16.3	17.2	18.0
1	2½	4½	1	9.5	17.1	60	18.7	19.6	20.6
1	2½	5	1	9.5	19.0	54	19.8	20.8	21.8
1	3	5	1	11.4	19.0	61	21.1	22.1	23.2
1	3	6	1	11.4	22.8	52	23.2	24.4	25.6

Note.—Variations in the fineness of the sand and the compacting of the concrete may affect the volumes by 10% in either direction.

†Use 50% column for broken stone screened to uniform size.

‡Use 45% column for average conditions and for broken stone with dust screened out.

§Use 40% column for gravel or mixed stone and gravel.

*Taken by permission from Taylor & Thompson's "Concrete, Plain and Reinforced," copyright, 1905, by Frederick W. Taylor. John Wiley & Sons, New York, publishers.

QUANTITIES OF MATERIALS FOR ONE CUBIC YARD OF RAMMED CONCRETE*

Based on a Barrel of 3.8 Cubic Feet

Proportions by Parts			Proportions by Volume			Volume of Mortar in Terms of Percentage of Volume of Stone	Percentages of Voids in Broken Stone or Gravel											
							+50 Per Cent.				+45 Per Cent.				§40 Per Cent.			
							Ce-ment	Sand	Stone	Packed Cement	Loose Sand	Loose Stone	Ce-ment	Sand	Stone	Ce-ment	Sand	Stone
1	1	2	bbl.	cu. ft.	cu. ft.	per cent.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.
1	1	3	1	3.8	7.6	75	2.85	0.40	0.80	2.73	0.38	0.77	2.62	0.37	0.74	2.62	0.37	0.74
1	1	3	1	3.8	11.4	51	2.34	0.33	0.99	2.22	0.31	0.94	2.12	0.30	0.90	2.12	0.30	0.90
1	1½	3	1	5.7	11.4	64	2.09	0.44	0.88	2.00	0.42	0.84	1.91	0.40	0.81	1.91	0.40	0.81
1	1½	3½	1	5.7	13.3	55	1.94	0.41	0.96	1.84	0.39	0.91	1.76	0.37	0.87	1.76	0.37	0.87
1	2	3	1	7.6	11.4	75	1.89	0.53	0.80	1.81	0.51	0.76	1.74	0.49	0.74	1.74	0.49	0.74
1	2	4	1	7.6	15.2	57	1.65	0.46	0.93	1.57	0.44	0.88	1.50	0.42	0.84	1.50	0.42	0.84
1	2½	4	1	9.5	15.2	66	1.52	0.54	0.86	1.46	0.51	0.82	1.40	0.49	0.79	1.40	0.49	0.79
1	2½	4½	1	9.5	17.1	60	1.44	0.51	0.91	1.37	0.48	0.87	1.31	0.46	0.83	1.31	0.46	0.83
1	2½	5	1	9.5	19.0	54	1.37	0.48	0.96	1.30	0.46	0.92	1.24	0.44	0.87	1.24	0.44	0.87
1	3	5	1	11.4	19.0	61	1.28	0.54	0.90	1.22	0.52	0.86	1.17	0.49	0.82	1.17	0.49	0.82
1	3	6	1	11.4	22.8	52	1.16	0.49	0.98	1.11	0.47	0.94	1.05	0.44	0.89	1.05	0.44	0.89

Note.—Variations in the fineness of the sand and the compacting of the concrete may affect the quantities by 10% in either direction.
†Use 50% columns for broken stone screened to uniform size.
‡Use 45% columns for average conditions and for broken stone with dust screened out.
§Use 40% columns for gravel or mixed stone and gravel.
*Quoted from Copyrighted Treatise; see footnote on opposite page.

VOLUME OF PLASTIC MORTAR MADE FROM DIFFERENT PROPORTIONS OF CEMENT AND SAND*

Quantities of Materials per Cubic Yard

Relative Proportions by Volume†		Volume of Compacted Plastic Mortar		Materials for 1 cu. yd. Compacted Plastic Mortar, Based on Barrel of 3.8 Cubic Feet	
Cement	Sand	From 1 cu. ft. Cement, Based on Portland Cement Weighing 100 Lbs. per cu. ft.	From 1 bbl., or 4 bags, Cement, Based on Barrel of 3.8 cu. ft.	Packed Cement	Loose Sand
		cu. ft.	cu. ft.	bbl.	cu. yd.
1	0	0.86	3.2	8.31	
1	1	1.42	5.4	5.01	0.71
1	1½	1.78	6.7	4.00	0.84
1	2	2.14	8.1	3.32	0.93
1	2½	2.50	9.5	2.84	1.00
1	3	2.86	10.9	2.48	1.05

Note.—Variations in the fineness of the sand and the cement, and in the consistency of the mortar may affect the values by 10% in either direction.

*See reference, footnote, p. 18.

†Cement as packed by manufacturer, sand loose.

RUBBLE CONCRETE.

Rubble concrete is ordinary concrete in which are imbedded large stones, usually of a size that can be handled by one or two men, but in very massive work such as large dams, stones of even greater size as heavy as can be handled with a derrick are used. Only in massive structures such as heavy foundations, dams, retaining walls, or similar works is this form of construction possible and when stones are imbedded in the concrete they should be spaced at least 3 inches from one another and also from the outer surface. About 20 per cent of the total volume of the structure may be replaced by "one-man" and "two-men" stones, and thus a considerable saving in cost is effected in large structures.

MIXING CONCRETE.

Mixing may be done either by hand or machine and the method to be employed is determined principally by the size of the job. If a small amount of concrete is to be made, hand mixing is the more economical, while for large works machine mixers are better and generally cheaper, though in some cases where the mixer must be frequently moved, hand mixing may prove to be the cheaper. A better and more uniform concrete can be made with a good ma-

chine mixer than by hand. The type of mixer should be such as to insure a thorough and uniform mixing of the materials. In any case enough water should be used to make a mushy consistency which requires very little tamping to bring the mortar to the surface.

HAND MIXING.

If hand mixing is employed it should be carefully done on a water-tight platform and should be subjected to thorough supervision. The following directions by Taylor and Thompson for hand mixing will be found useful to those who are inexperienced in this class of work.*

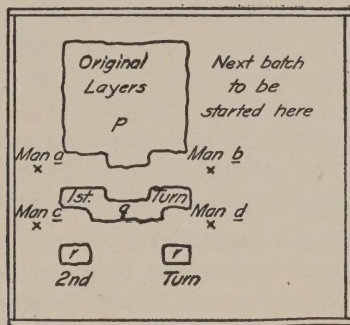


FIG. 1.—POSITION OF MEN AND CONCRETE ON PLATFORM WHILE TURNING.*

“Assume a gang of four men to wheel and mix the concrete with two other men to look after the placing and ramming.

“When starting a batch, two mixers shovel or wheel sand into the measuring box or barrel—which should have no bottom or top—level it and lift off the measure, leveling the sand still further if necessary. They then empty the cement on top of the sand, level it to a layer of even thickness, and turn the dry sand and cement with shovels three times, as described below, after which the mixture should be of uniform color.

“While these two men are mixing sand and cement, the other two fill the gravel measure about half full, then the two sand men take hold with them, and complete filling it. The gravel measure is lifted, the gravel hollowed out slightly in the center, and the mixture of sand and cement shoveled on top in a layer of nearly even thickness.† A definite number of pails are filled with

*See reference, footnote, page 18.

†“Some Engineers prefer to spread the stone on top of the sand and cement, while others prefer to mix the water with the sand and cement before adding them to the stone.”

water, and poured directly on the top of these layers, greater uniformity being thus attained than by adding the water directly from a hose. After soaking in slightly the mass is ready for turning.

"The method illustrated in Fig. 1 of turning with shovels materials which have already been spread in layers is as follows:

"Two men, A and B, with square-pointed shovels, stand facing each other at one end of the pile to be turned, one working right-handed and the other left-handed. Each man pushes his shovel along the platform under the pile, lifts the shovelful, turns with it, and then, turning the shovel completely over, and with a spreading motion drawing the shovel toward himself, deposits the material about 2 feet from its original position. Repetitions of this operation will form a flat ridge of the material, on a line with the pile as it originally lay, and flat enough so that the stones will not roll. As soon as, but not before, a single ridge is complete, two other men, C and D, should start upon this ridge, turning the materials for the second time, as shown in the illustration, and forming as before a flat ridge and finally a level pile which gradually replaces the last. A third mixing is accomplished in a similar way.

"Fig. 1 gives the position of the piles as the concrete is being turned. A portion of the original layers is shown at P, the ridge formed by men A and B shoveling from pile P is shown at Q, and the beginning of the ridge formed by men C and D is shown at RR. The third turning is not shown.

"The quantity of water used must be varied according to the moisture in the materials and the consistency required in the concrete. While the opinions of engineers regarding the proper consistency vary widely, it is advisable, the authors believe, for an inexperienced gang to use an excess of water. The rule may be made in hand mixing to use as much water as can be thoroughly incorporated with the materials. Concrete thus made will be so soft or 'mushy' that it will fall off the shovel unless handled quickly.

"After the material has been turned twice, as described, and as soon as the third turning has been commenced, two of the mixers who have finished turning may load the concrete into barrows and wheel to place. They should fill their own barrows, and after the mass has been completely turned for the third time by the other two men the latter should start filling the gravel measure for the next batch.

"If the concrete is not wheeled over 50 feet, four experienced men ought to mix and wheel on the average about $10\frac{1}{2}$ batches in ten hours. This figure is based on proportions 1:2 $\frac{1}{2}$:5, and assumes that a batch consists of one barrel (four bags) Portland cement with 9.5 cubic feet of sand and 19 cubic feet of gravel or stone.

"Assuming that 1.29 barrels of cement are required for 1 cubic yard of concrete, one barrel of cement—that is, one batch—will make 0.78 cubic yard of concrete; hence $10\frac{1}{2}$ batches mixed and wheeled by four men in ten hours are equivalent to $8\frac{1}{4}$ cubic yards of concrete. This is for the very simplest kind of concreting and makes no allowance for the labor of supplying materials to the mixing platform or for building forms."

PLACING CONCRETE.

In handling and placing concrete, the materials must remain perfectly mixed, the aggregate must not separate from the mortar and the concrete must be rammed or agitated so as to thoroughly fill the forms and surround all parts of the steel reinforcement. Care must be taken to remove all sticks, blocks, shavings, or similar materials from the forms before the concrete is placed and in case new concrete is deposited on a layer that has already set, the old surface should be roughened, cleaned, and drenched with water before the new material is added. In reinforced structures the metal must be placed in the forms and wired or otherwise held rigidly in position before any concrete is laid. It is now generally customary to use wet mixtures and the concrete is usually carried in buckets or in water-tight wheelbarrows. An ordinary wheelbarrow load of concrete is about 1.9 cu. ft. If wet concrete is used it can be dropped vertically into place or run through an inclined water-tight chute. Concrete should be wet frequently for a few days after it is laid.

LAYING CONCRETE IN WATER.

Only in exceptional cases should concrete be placed in water and even then the greatest care must be taken to prevent the cement from being washed out. Under no circumstances should it be thrown or placed into water by shovels. In some cases of small construction, the concrete may be deposited in bags, or it may be placed in pails with a board covering the top of the pail and lowered carefully into the water to the bottom. When this has reached bottom, turn the pail upside down and move the board from underneath and carefully raise the pail, allowing the concrete to flow out. Great care must be taken not to disturb the water in which the concrete is being placed nor to touch the concrete before it has set. Under no circumstances should concrete be placed in running water. In large work, it is sometimes placed by means of a tube extending into the water with the lower end near the bottom. By keeping a continuous flow of concrete passing through the tube, the cement will not be separated from the aggregate.

LAYING CONCRETE IN SEA WATER.

For use in sea water concrete must be proportioned to secure maximum density and must be so carefully mixed and placed as to secure an impervious mass. Unless proper precautions are taken in choosing the materials, mixing, and in depositing the concrete there is danger of scaling on the surface of the concrete between high and low water levels.

The remarks just made concerning the use of concrete in sea water are equally true of concrete placed in alkaline soils where the mixture must be of maximum density and must be richer than where used in ordinary soils.

EFFECT OF MANURE.

Manure, because of the acid in its composition, is injurious to green concrete, but after the concrete is thoroughly hardened it satisfactorily resists such action.

FREEZING.

Concrete for thin walls and reinforced concrete structures should not be laid during freezing weather unless concrete is prevented from freezing by warming the materials before mixing and by covering the concrete after it is placed with a thick covering of clean straw, sand, or other suitable material. Common salt is quite frequently used to lower the freezing point of the water used in mixing concrete. A well known rule requires 1 per cent by weight of the salt to the weight of the water for each degree Fahrenheit below freezing point of water.

As one cannot tell in advance how low the temperature is going to fall, an arbitrary amount of salt must be used. Some engineers specify two pounds of salt to each bag of cement, and in case this is not sufficient, three pounds to a bag.

Another method is to mix warm sand and stone with the cement and water in such manner as will bring the entire mixture up to about 75 degrees Fahrenheit, protecting in the early stages of setting, so far as possible, from cold and currents of air.

Heavy walls and foundations where the appearance of the faces is of no importance may be laid in freezing weather.

Concrete sidewalks must not be laid in freezing weather, for the surface will soon scale.

FORMS.

Forms usually are of wood, though in some cases metal is used. They must be strongly built so as to prevent displacement, deflection, or leakage of mortar and they must not be removed until the concrete has set. The time required for setting varies with the condition of the weather, longer time being required in cold or wet weather; with the quality of the cement; and with the amount of water used in mixing. White pine is the best lumber for forms, but cheaper kinds, such as spruce, fir, Norway pine or softer kinds of Southern pine, are frequently used, and green lumber is on the whole better than dry. To secure a smooth surface on the finished concrete, lumber planed on one side must be used; likewise where the forms are to be removed within a day or two, planed lumber must be used, for then the concrete will not stick to the planks and they may be again used without much cleaning.

Forms usually consist of boards held in place by studs braced so as to remain in place. For the boards one or two-inch planks are commonly used

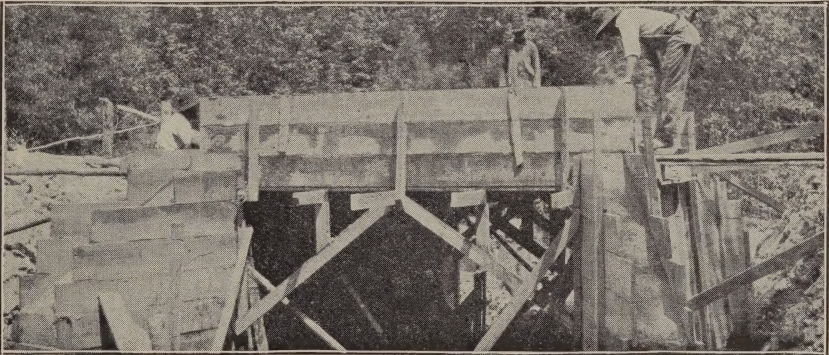


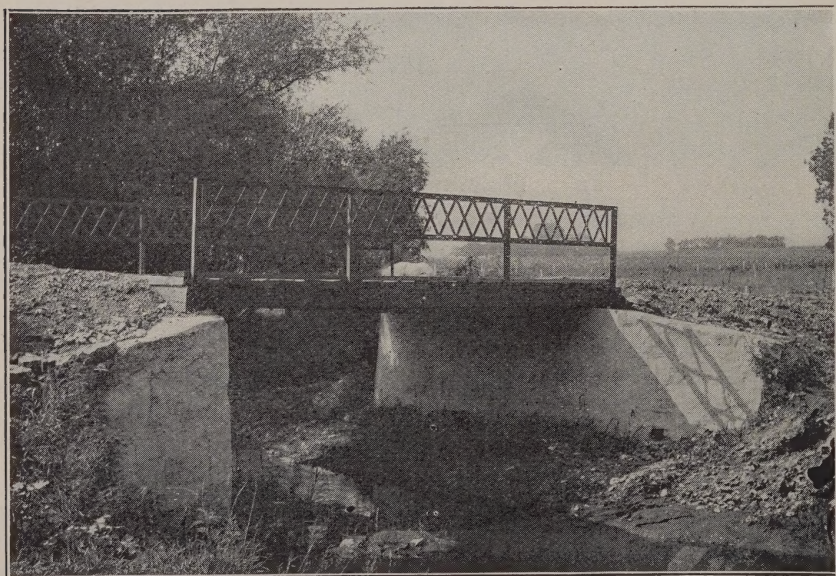
FIG. 2.—FORMS FOR BEAM BRIDGE

and quite frequently tongued and grooved materials are necessary for tight construction. The studs are spaced at distances apart depending upon the consistency of the concrete, the thickness of the wall, and the character of finished concrete surface desired. Wet concrete in large masses is apt to exert considerable pressure against the forms before the cement sets, but with wet concrete less ramming is necessary than with dry mixtures and therefore the forms are less likely to be knocked out of position. With wet mixtures in comparatively thin walls two-inch planking should be supported not over 5 feet apart, while for one-inch boards 2 feet is about the right spacing.

Forms are greased by applying to them a coat of crude oil or soft soap, but if the forms are not to be removed for several weeks no greasing is necessary, though in this case the surfaces of the forms which are to come in contact with the concrete must be thoroughly wet.



PAVEMENT IN CITY OF PANAMA.



BRIDGE NEAR WASCO, ILL.

CHAPTER II.

SIDEWALKS, CURBS, AND GUTTERS.

Concrete is in universal use for sidewalks, curbs, and gutters, and the excellent and permanent qualities of this material are as well shown in these forms as in any other type of construction in which it is used. Sidewalks should be smooth, durable, cheap in first cost, and should present a pleasing appearance. With proper care concrete can be laid to satisfy all these requirements and therefore make a solid durable walk. For curbs alone or for combined curbs and gutters, especially for the streets in residential districts, parks or similar places where neatness of appearance is especially desirable, concrete is being used in many localities almost exclusively. In this chapter are shown methods of construction which are standard and which if followed will produce good results.

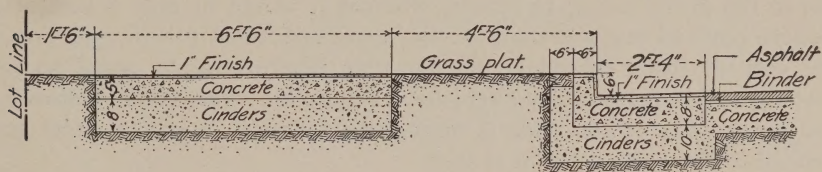


FIG. 3—CROSS SECTION OF SIDEWALK AND COMBINED CURB AND GUTTER.

DIMENSIONS OF WALKS, CURBS, AND GUTTERS.

A first-class walk consists of a foundation of cinders, gravel, or broken stone upon which is laid a layer of concrete called the base and an upper thin layer of mortar called the wearing surface. Granolithic is a common name for concrete walks.

Sidewalks vary in width according to conditions, but the thickness of the concrete is nearly uniform, ranging from four to five inches total thickness including the wearing surface.

In Fig. 3 is shown the section of a sidewalk separated from the curb by a narrow grass plat such as is common in residential streets. The thickness of the concrete is shown as 5 inches, but 4 inches is more commonly used, and if the walk is provided with good foundations and drainage 4 inches is ample in most places. Where the total thickness of the concrete is 4 inches the base should be $3\frac{1}{4}$ or 3 inches and the wearing surface $\frac{3}{4}$ or 1 inch, and for a 5-inch walk the base should be 4 inches and the wearing surface 1 inch.

The slope of the surface from the lot line toward the curb should be $\frac{1}{4}$ or $\frac{3}{8}$ inch per foot. For parks and similar locations the walk is usually crowned toward the center.

Curbs are made from 6 to 8 inches wide on top and are generally vertical on the side next to the walk and slightly inclined on the side facing the gutter. The total depth of the curb should be from 12 to 14 inches, and if the street traffic is heavy the curb should set upon a concrete base 12 inches wide and 8 inches thick. Where the curb and gutter are combined, as shown in Fig. 3, the gutter is made 8 inches thick and from $1\frac{1}{2}$ to 3 feet in width. In the case shown the curb has a width on top of 6 inches and tapers down to $6\frac{1}{2}$ inches at the gutter. Sometimes both the inner and outer surfaces of the gutter are made vertical, although it is better to have the front face inclined. The upper outer corner of the curb and the intersection of gutter with face of curb should be rounded off with radii of about 1 inch.

The surface of the gutter should conform to that of the street surface, though in some cities, as for instance Salt Lake City, the upper surface of the gutter is curved in such a manner as to secure greater carrying capacity, the depth of the gutter being 10 inches, whereas it would be only 8 inches were the curve omitted and the slope of the street continued to the curb line. At street corners curbs should be thicker than where straight so as to better withstand shocks from moving vehicles. Where the street traffic is heavy, the upper outer edge of the curb is often provided with a special steel corner imbedded in the concrete as it is laid.

Fig. 4 illustrates a type of concrete curb, gutter, and cross walk construction used considerably in Chicago on streets for ordinary traffic. A cross walk is provided by elevating the street surface near the curbs as shown.

FOUNDATIONS AND DRAINAGE.

A good foundation properly drained is absolutely essential for successful sidewalk construction, and is best made by excavating the soil to a depth of 10 to 15 inches below the level of the finished sidewalk surface, depending on the kind of soil and the locality, so as to give a foundation 6 to 10 inches thick, and after ramming the bottom of the excavation a layer of coarse material such as broken stone, cinders, or coarse sand is placed in the excavation and thoroughly rammed. Drainage and ramming are of the utmost importance. In some cities no foundation is required in soils of clean coarse sand which is porous enough to afford good drainage, while in soils which retain water a foundation of 6 to 12 inches is specified. Fig. 3 shows an 8-inch foundation of cinders under the walk and one of 10 inches under the curb and gutter. Broken stone or gravel should be screened

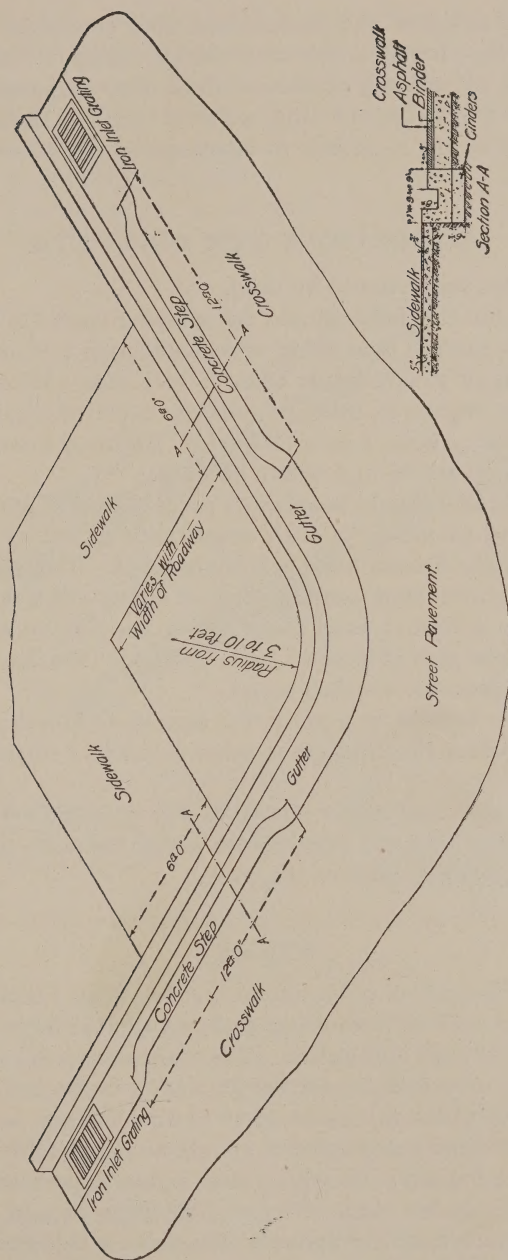


FIG. 4.—CONCRETE CURB AND GUTTER, AND CROSS-WALK CONSTRUCTION.

to remove all fine material and cinders and sand should be wet while being rammed into place. In soils like clay which retain water the foundation should be drained by running occasional drain tiles underneath the soil from the foundation to the gutter, or other suitable outlet. Instead of tile drains small ditches, say 10 by 10 inches in cross section, filled with broken stone may be used.

PROPORTIONS FOR CONCRETE.

Portland cement only should be used.

The concrete for the base should be mixed 1 part "ATLAS" Portland Cement, $2\frac{1}{2}$ parts sand or fine stone which will pass a $\frac{1}{4}$ -inch screen, and 5 parts broken stone or gravel larger than $\frac{1}{4}$ inch size. Where the quality of the sand and stone require it, these proportions must be slightly changed, and if the sand is not very good 1 part "ATLAS" Portland Cement, 2 parts sand and 4 parts stone or gravel had better be used.

The wearing surface should be mixed 1 part "ATLAS" Portland Cement to $1\frac{1}{2}$ parts sand, and should be of such consistency as not to require tamping, but should be simply floated with a straight edge. The sand here referred to may be either natural bank sand or crushed stone which will pass a $\frac{1}{4}$ -inch screen provided it is from a hard stone which has but little dust.

Another excellent plan is to use 1 part "ATLAS" Portland Cement and $\frac{3}{4}$ part sand and $\frac{3}{4}$ part fine crushed stone.

Although 1 part cement to 2 parts fine aggregate is quite frequently used for the wearing surface this mixture is liable to make a surface that will wear sandy.

The combined curb and gutter shown in Fig. 3 is laid on a cinder foundation and the concrete base and 1-inch finish are of the same mixtures as specified for the corresponding parts of the walk.

FORMS.

Forms should be made of clean lumber not less than 2 inches thick, though $1\frac{1}{2}$ may be used if well braced. Fig. 5 shows typical form construction for walks and combined curb and gutter. The walk shown is 5 inches thick and the side forms are 2 by 6 inches, although 2 by 5 inches will do if available. The upper edge must be the exact level of the finished walk. The forms should be of best white pine planed on all sides, should be straight and set to true line and grade. If white pine is too expensive, spruce, fir, or other soft woods may be used. The wooden pegs should be spaced from 4 to 6 feet apart and must be securely driven into the ground so that the forms will not move while concrete is being deposited against them.

The gutter shown as 5 inches thick in the drawing is suitable for streets with light traffic. The curb is 6 inches wide and 11 inches deep with both faces vertical. The side planks are held in place by the wooden pegs and the front plank for the curb is held by clamps and steel dividing plates, the latter serving as spacers as well as dividing plates at the joints. The upper corner of the curb should be rounded to a radius of 1 inch with a tool and the lower corner at the intersection of the gutter and curb should be similarly arranged by rounding off the lower inner edge of the front plank of the curb form.

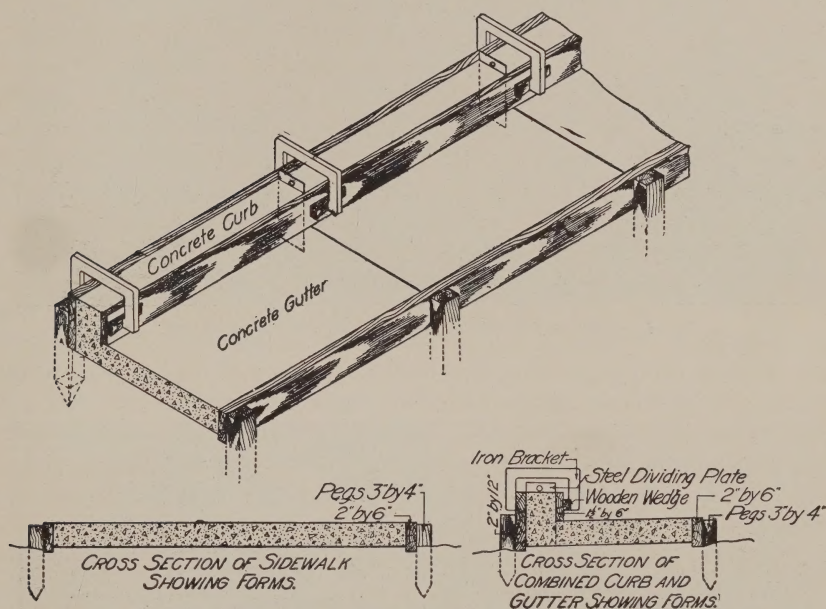


FIG. 5.—FORMS FOR SIDEWALK AND COMBINED CURB AND GUTTER

PLACING CONCRETE.

After having placed and thoroughly rammed the porous foundation, and having carefully set the forms to line, as described above, divide the surface into blocks by cross lines. Mark the dividing lines between the blocks on the side forms by notches and place cross strips from form to form located by these notches. The blocks should be nearly square, and for walks 4 inches in thickness should not be over 6 feet in longest dimension, while for walks 5 inches in thickness 8 feet is about the maximum size. By laying alternate blocks, and then after the concrete has stiffened, removing the cross strips and filling in the blocks between, joints are made so that if the walk heaves

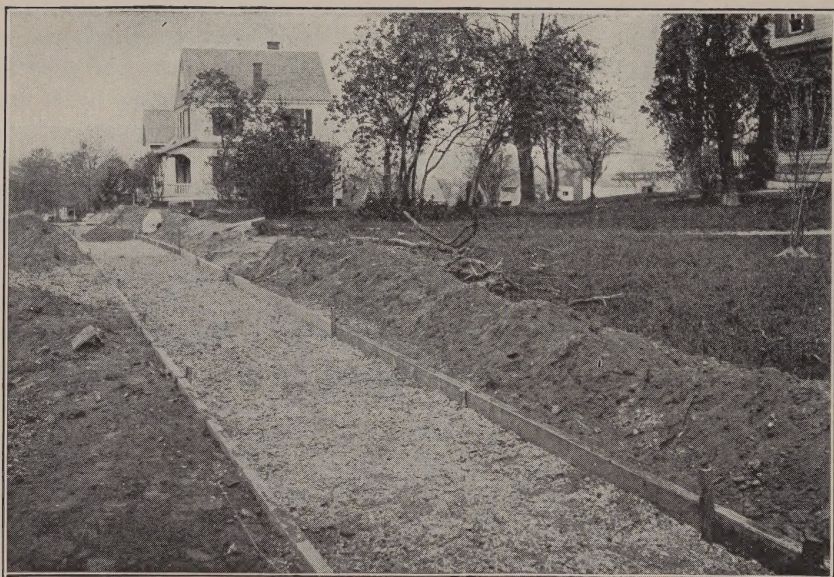


FIG. 6.—CINDER FOUNDATION FOR CONCRETE SIDEWALK.

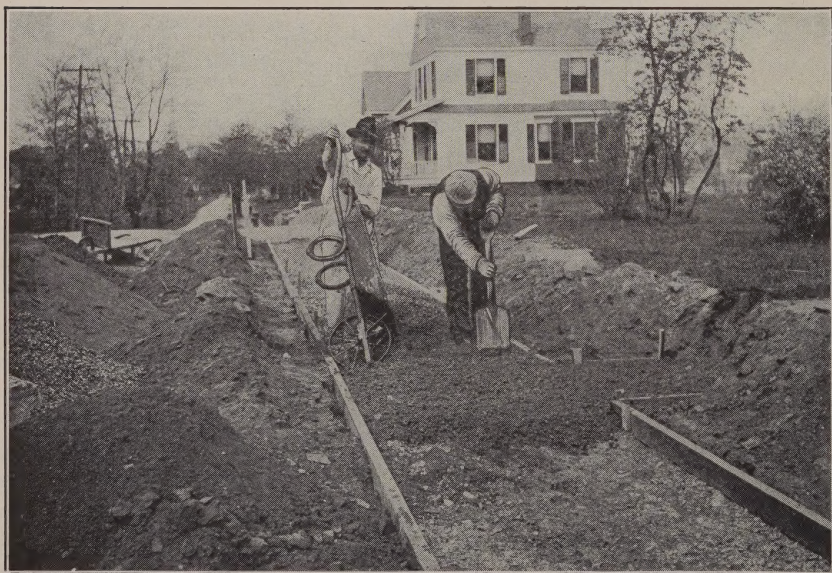


FIG. 7.—PLACING THE CONCRETE BASE.

slightly, it will crack in the joint and will not show, provided of course the wearing surface is grooved and jointed directly above the joint in the base.

Mix the concrete for the base on a tight platform unless the street pavement is hard and impervious, in which case that can be used for mixing. Make the consistency rather stiff, but wet enough so that the concrete will glisten when it is being mixed, and although holding its shape in a pile, can be compacted and the mortar brought to the surface with comparatively light ramming. See that the surface of the base is exactly one inch below the upper level of the forms, so that the wearing surface will be uniformly one inch thick. To accomplish this, make a straight-edge of $\frac{7}{8}$ inch wood notched at each end to fit upon the forms.

As soon as a few blocks of the base have been laid, and before the concrete has set, mix the mortar for the wearing surface. Make this one part "ATLAS" Portland Cement to one and a half parts sand or finely crushed stone and sand mixed. This mortar may be mixed in a mortar box, as it has to be of about the consistency of mortar for laying brick.

To secure good results and prevent the wearing surface from eventually cracking from the base, it is absolutely essential that the mortar be spread before the concrete base has begun to stiffen, for if it is left for several hours or over night the wearing surface is almost sure to peel off in places.

After smoothing the wearing surface with a straight-edge, float it roughly with a plasterer's trowel, and after a few hours, when the mortar has begun to stiffen, float it with a wooden float, and then with a metal float, or, as it is sometimes called, a plasterer's trowel. Neat cement should not be applied to the surface. Just as the final floating is being finished, take a small pointing trowel, and guided by the notches in the side forms and by a straight-edge, placed across the walk, run the trowel down between the blocks so as to form a joint in the wearing surface directly above the joint in the base, and finish this joint with a groover, so as to give it rounded edges. The side edges of the walk are then rounded off with a special jointer, and the surface again finally troweled.

If a roughened surface is desired, a dot roller or a grooved roller may be used. The walk should be protected from the sun for at least four days, and wet down frequently.

Curbs and gutters should be laid in advance of the walk in sections 5 or 6 feet in length and a joint should be left between the curb and the walk. The surface of the gutter and the top and front surface of the curb should be made of a 1-inch layer of mortar the same as used for the wearing surface of the walk. It is important to place the upper part of the curb at the same time with the lower, for the perfect union of the two parts is necessary to keep the curb in position.



FIG. 8.—MIXING MORTAR FOR WEARING SURFACE.



FIG. 9.—TROWELING WEARING SURFACE.

COLORING MATTER.

By selecting a crushed stone of the proper variety a permanent color can be secured for the surface of a walk, some pink granites giving especially pleasing effects. Artificial coloring matter may be secured by the addition of lamp black, ochre, iron oxide, and other materials to the cement, but most of these colors will fade.

MATERIALS FOR CONCRETE SIDEWALKS, FLOORS AND WALLS

Bags of Cement to 100 sq. ft. of Surface area of Concrete Base or of Wall				Bags of Cement to 100 sq. ft. of Mortar Surface			
Thick- ness, Inches	Proportions			Thickness, Inches	Proportions		
	1:1½:3	1:2:4	1:3:6		1:1	1:1½	1:2
3	8½	6½	4¾	½	3½	2¾	2½
4	11	8¾	6	¾	5	4	3½
5	14½	11	7½	1	7	5¼	4½
6	16¾	13¼	9½	1¼	8¼	6½	5¾
8	22¾	18	12	1½	10	8	6½
10	28¾	21½	15½	1¾	12	9¼	7¾
12	34¾	26½	18½	2	14	11	9

No. of sq. ft. of Concrete Laid with 4 Bags (1 bbl.) of Cement				No. of sq. ft. of Mortar Surface Laid with 4 Bags (1 bbl.) of Cement			
Thick- ness, Inches	Proportions			Thickness, Inches	Proportions		
	1:1½:3	1:2:4	1:3:6		1:1	1:1½	1:2
3	47	60	83	½	114	146	178
4	36	46	66	¾	80	100	114
5	27	36	52	1	57	73	89
6	24	30	41	1¼	48	60	70
8	17	22	33	1½	40	50	59
10	14	19	26	1¾	33	43	52
12	12	15	21	2	29	36	44

QUANTITIES OF MATERIALS FOR SIDEWALKS.

For the computation of the quantities of cement, sand, and stone required to construct a sidewalk of any given dimensions the accompanying table will be found useful as giving the quantities required to lay 100 square feet of sidewalk. The values given are based on a barrel of 3.8 cubic feet and a coarse aggregate having 45 per cent voids are assumed. In the table allowances have been made for waste. To determine the total volumes required for a walk of given proportions and dimensions the amounts noted for the base and for the wearing surface should be added together. The quantities required will of course vary with the proportions and character of the materials.

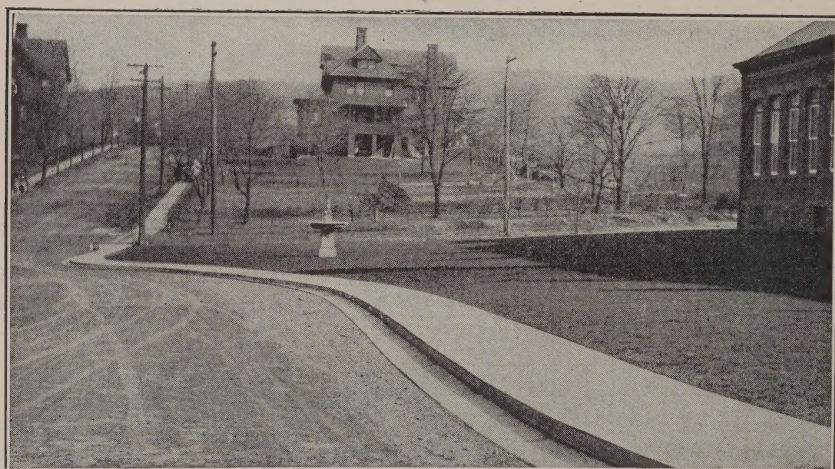


FIG. 10.—CONCRETE SIDEWALK IN SOUTH BETHLEHEM, PA.

COST.

The cost of sidewalks, curbs and gutters varies with the locality, size of the job, and with the character of the soil and materials used. Work finished recently under contract for Salt Lake City shows the following costs to the city. These figures are based on a day's work of eight hours and laborers at \$2 per day, form setters \$4 per day. Costs given below are per linear foot:

Concrete curb, 6 x 16 inches, without gutter.....	\$0.43
Concrete curb, plain, 6 x 16 inches, with gutter 30 inches wide.....	0.79
Concrete curb, plain, 6 x 16 inches, with gutter 30 inches wide and curved to special radius	0.85
Concrete curb, 6 x 16 inches, reinforced, without gutter and curved to special radius	0.64
Concrete gutter, 30 inches wide along curb.....	0.61

Mr. George W. Tillson* gives the cost of concrete walks, 5 inches thick and laid on 7 inches of cinders in Brooklyn, N. Y., as $16\frac{1}{2}$ cents per sq. ft.

Fig. 10 shows a walk built of "ATLAS" Portland Cement in South Bethlehem, Pa., where the current price for walks similar to that shown is from 17 to 20 cents per sq. ft. including curb and gutter. The walk is 4 feet wide, has a 3-inch base of 1:2:4 concrete and a wearing surface of 1:2 mortar, and is laid

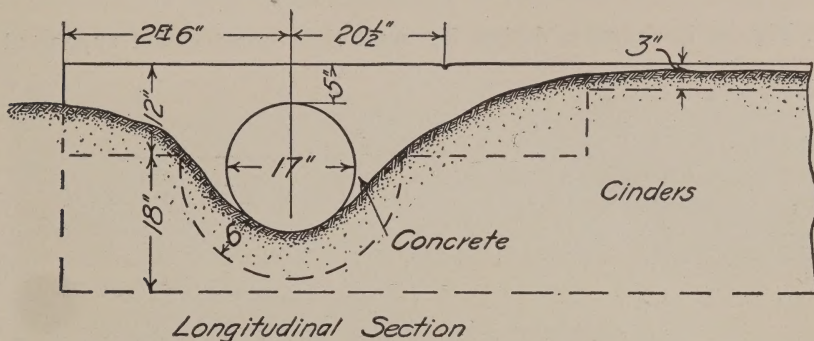


FIG. 11.—CONCRETE CROSS-WALK OVER GUTTER.

on an 18-inch cinder foundation. The front face of the curb is 4 inches high and the gutter is 14 inches wide and 4 inches thick. Street traffic is light so that heavy curbs and gutters are not required at this location.

Fig. 11 and Fig. 12 show a small cross-walk leading from a front walk in a yard over a gutter to a country road. The walk is 4 feet in width and the total length from house to road is $13\frac{1}{2}$ feet. The walk in the yard is 3 inches

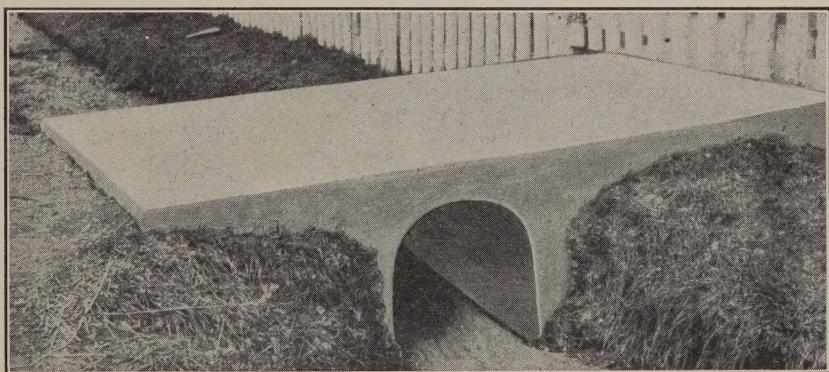


FIG. 12.—CONCRETE CROSS-WALK OVER GUTTER.

*"Street Pavements and Paving Materials," p. 479.

thick, and on each side of the circular opening is 12 inches thick, while under the opening there is a thickness of 6 inches. An 18-inch cinder foundation underlies the whole work. Two cement barrels were used in place of forms and the total cost of the walk and cross-walk was \$13.20, or 24½ cents per sq. ft.

VAULT LIGHT CONSTRUCTION.

In Fig. 13 is shown a design for vault light construction supported on

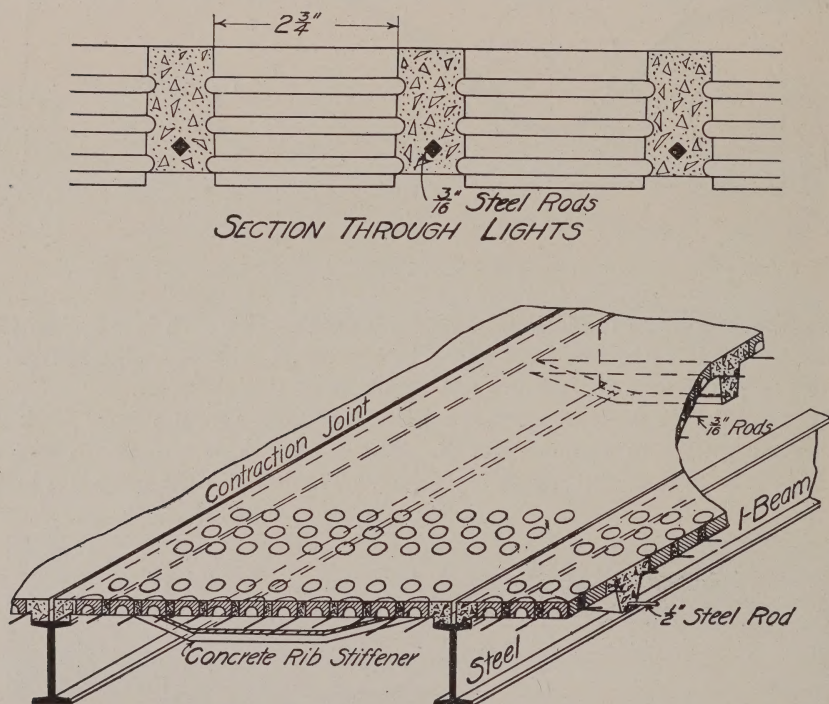


FIG. 13.—TYPICAL VAULT LIGHT CONSTRUCTION.*

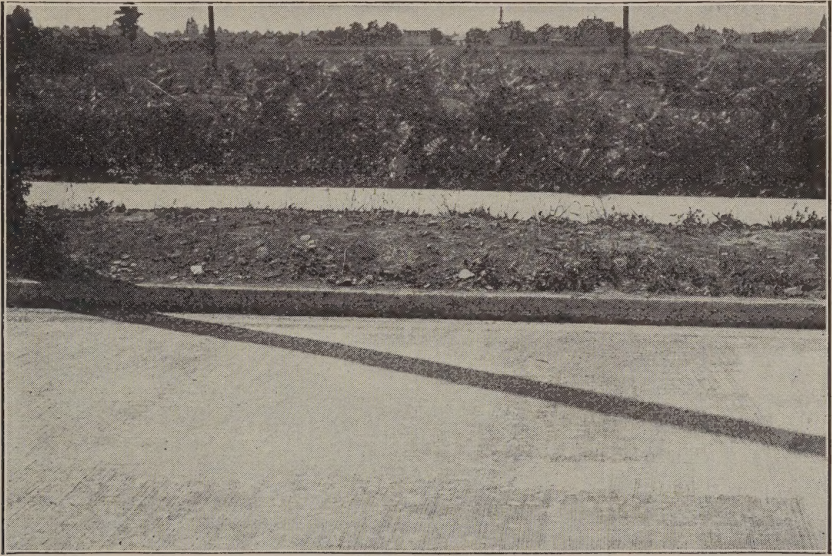
concrete ribs on steel I-beams. The sizes of the concrete ribs and the steel I-beams depend on the spans, and it is necessary to construct the concrete ribs and slab at one time. The glass discs are imbedded in the concrete and admit light to the area below.

*See reference, footnote, page 18.

CHAPTER III.

STREET PAVEMENTS.

The ideal street pavement is durable, noiseless, cleanly, easy to travel on, low in first cost, and built of such material that the maintenance charges are small. Scarcely any material has been found which entirely satisfies these requirements, but some of the pavements of Portland cement concrete which have been built in recent years, where the concrete forms not only the founda-



HASSAM PAVEMENT, PORTLAND, OREGON.

tion but also the wearing surface, are giving thorough satisfaction and approach closely to the ideal for streets where the traffic is not so excessive as to require a stone block.

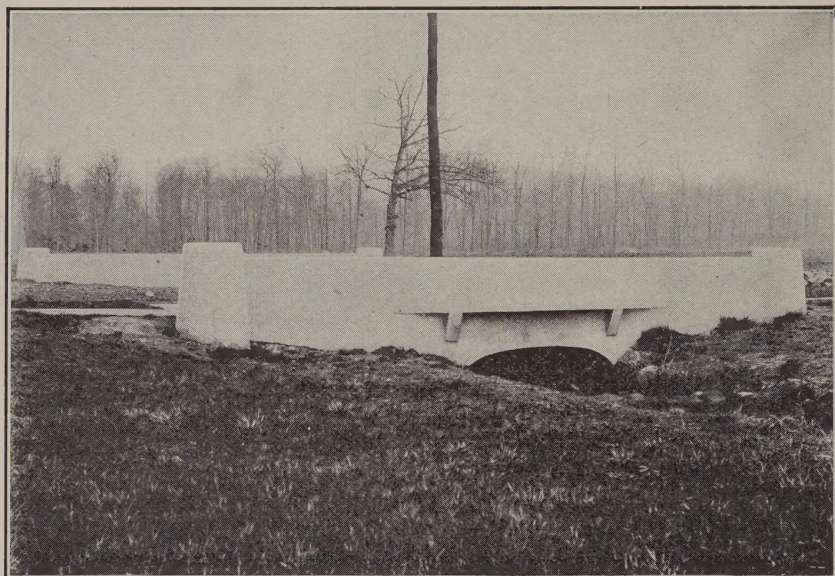
For pavement foundations, concrete is used almost universally in city streets where the wearing surface is asphalt, brick, wooden blocks or stone blocks, and there is no material which can be compared with it for this purpose. Its use for the wearing surface is comparatively new, but it is proving its usefulness to a remarkable degree.

Concrete sidewalks made of a concrete base with a granolithic or mortar wearing surface have been in successful use ever since the beginning of the Portland cement industry. As early as 1894 alleys were paved with concrete in Boston, using methods similar to sidewalk construction except slightly

thicker layers of concrete and surface divisions into small blocks instead of large ones, so as to give better footing for horses.

Probably the first street pavement of concrete was built in Richmond, Ind., in 1903, on Sailor Street, and in 1906, when it was necessary to cut a trench the entire length of this pavement for telephone conduits, the concrete was found so hard that it could be cut only with great difficulty. On the completion of the conduit the pavement was repaired, and in 1908 it seemed to be as good as when laid in 1903.

An alley pavement in Richmond adjacent to the Wescott Hotel, and built



BRIDGE AT HAWORTH, N. J.

in 1896, in which a very heavy traffic is confined to a small space, proved so satisfactory that the street pavement was an outgrowth of it. An examination of this alley in 1908 showed the surface to be in good condition with very little signs of wear.

Concrete street pavements contain the maximum number of desirable qualities as compared with pavements of other materials. They are low in first cost, since the materials of which they are made are within easy reach of all localities desiring good pavements. Practically no section of the country is without stone or gravel good enough for the main body of the pavement,

and if local sand is too poor in quality and freight rates prohibit importing good sand, fine crushed stone may be used in its place. "ATLAS" Portland Cement is within the reach of every section of the country.

The quality of materials and workmanship for concrete pavements is of greater importance than in almost any other form of concrete construction. The aggregate must be chosen with extreme care, the cement must be of a first-class standard brand, the proportioning of the materials must be accurate, and the consistency right. Concrete roadways require expert workmanship but no more so than the laying of other forms of pavement. The methods of laying and the materials to employ are best understood by reference to the descriptions given in the pages which follow of pavements which have proved successful. Too great stress cannot be laid upon the matter of a first-class aggregate for the wearing surface; if this cannot be obtained concrete street paving should not be attempted.

The maintenance cost of concrete pavements is very low. They are not injured by the elements or by materials which attack some forms of pavement. The cost of maintenance of a pavement includes the cost of keeping it clean and concrete can be easily cleaned by flushing the street with water, since this does not in the least injure the quality of the concrete whereas with some other pavements constant flushing is extremely injurious.

The item of smoothness is to a large degree within the control of the builder of the concrete pavement; for the surface can be made perfectly smooth or it can be left with any degree of roughness by grooving the surface or otherwise. Clearly, on a steep grade the pavement should be left so that horses can get a foothold and on curves so that automobiles will not slip. Both of these conditions can be met by grooving or roughening the wearing surface of the concrete.

A wagon running over a concrete pavement makes less noise than running over a stone block or other similar pavement having many joints. Another advantage of these pavements is that there are very few places where dust and dirt can collect.

Summing up then the advantages of concrete pavements it is seen that they offer very little resistance to moving vehicles, afford good foothold for horses and prevent slipping of fast moving automobiles, are clean, can easily be kept free from dirt, and are not very noisy. A pavement combining all these desirable qualities is certainly one that should commend itself to those in charge of construction and maintenance of our city streets.

CONCRETE STREET PAVEMENT FOUNDATIONS.

Concrete was first used in foundations for street pavements in New York City in 1888. At the present time nearly all cities require that concrete foundations shall be laid under all classes of pavements. It is well understood

that the success of any pavement depends largely upon its foundation. To insure a good foundation the subsoil should be properly shaped and graded and then thoroughly rolled with a steam roller weighing not less than 10 tons. When rolling the sub-grade care should be taken to remove all timbers or other matter which may decay and leave space underneath the foundation. All ditches or holes must be filled and any soft material removed and replaced by good, dry gravel or similar materials.

PROPORTIONS OF CONCRETE FOR STREET FOUNDATIONS.

The proportions of materials for concrete to be used in foundations for pavements such as granite blocks or asphalt depend upon the local conditions. The heavier the traffic the stronger should be the foundation. The proportions most common are 1 part "ATLAS" Portland Cement, 3 parts sand, and from 5 to 7 parts broken stone or gravel. In most cases 1 part "ATLAS" Portland Cement, 3 parts sand, and 6 parts broken stone or gravel makes a first-class foundation. The thickness of foundations of Portland cement concrete should be 6 inches. The surface of the concrete should be kept wet for a few days.

One square yard of concrete foundation 6 inches thick will require $\frac{1}{6}$ of a cubic yard of concrete. If the mixture is 1:3:6, as previously specified, the quantity of cement, sand, and broken stone in a square yard of foundation can easily be determined from the tables of quantities in Chapter I, page 19, by dividing the quantities given by 6. Thus, for 1 square yard of 6-inch foundation made of a 1:3:6 mixture there will be required 0.185 barrels of cement, 0.078 cubic yards of sand, and 0.157 cubic yards of stone. These figures are based on average conditions, that is, 45 per cent of voids in the broken stone. Quantities may also be found still more directly from table in Chapter II, page 27.

COST OF CONCRETE FOUNDATIONS IN PLACE.

The cost of concrete foundations for pavements varies greatly with the proportions used and with the cost of the materials and labor. The cost ranges from 75 cents to \$1.50 per square yard for the usual thickness of 6 inches. The following is an estimate for the cost of 1 cubic yard of 1:3:6 concrete in place making 6 square yards of finished foundation. For other prices of materials and labor the items may be varied accordingly.

Portland Cement, 1.11 barrels, \$2.00.....	\$2.22
Sand, 0.47 cu. yd., 75 cents.....	0.35
Broken Stone, 0.94 cu. yd., \$1.75.....	1.65
Labor with wages at 20 cents per hour.....	1.15

Cost of 1 cubic yard, that is, 6 square yards of foundation of 1:3:6 concrete in place	\$5.37
Cost of 1 square yard of 6-inch foundation.....	0.90

MIXING OF CONCRETE.

Machine mixing gives a better quality of concrete than hand mixing, but unless a large area is to be concreted and the machinery is very carefully selected and arranged, hand mixing is apt to be cheaper and is therefore more commonly used. For hand mixing a tight matched board or metal platform should be used, and the methods should conform to those outlined in Chapter I. The consistency of the concrete may be somewhat dryer than for reinforced concrete work, but should be wet enough so that the mortar will flush the surface with a very little ramming.



FIG. 14.—CONCRETE ROAD AT FLUSHING, L. I., N. Y

GANG FOR HAND MIXED CONCRETE.

To illustrate the arrangement of a gang in street pavement foundation work, the following example is taken from actual practice:*

Gang for a 6-inch foundation for a street pavement, where the sand and cement were made into a mortar and spread on to the stone, and where two mixing platforms were used, one on each side of the street, with a mortar box between them.

"One foreman.

"Two men mixing mortar in one mortar box.

"Four men shoveling stone alternately into two measuring boxes.

"Four men working alternately on the two mixing platforms, spreading mortar on stone, mixing concrete, and shoveling to place.

"Three men leveling and ramming concrete, and also assisting to shovel to place.

"One man carrying water and doing other odd work.

"The total quantity of concrete in proportions 1: 2: 5 laid per day of ten hours averaged from 40 to 46 batches or 29 to 33 cubic yards per day for the gang. The gang was not quite up to the average, for under given conditions they ought to have turned out regularly 34 cubic yards per day of ten hours."

*See reference, footnote, page 18.

CONSTRUCTION OF FOUNDATIONS.

The whole operation of mixing and depositing concrete in pavement foundations should be carried on as quickly as is possible with thoroughness. Concrete which has been mixed and has set or hardened to any extent should not be allowed to be used in the foundation. Wherever possible the concrete should be laid entirely across the street without longitudinal joints. Boards set to proper elevation and curved on the upper edge to conform to the cross section of the foundation are set across the street and between these forms the concrete is laid.

When connection is to be made with any section which has been previously laid and which is partially or wholly set the edge of such section must be broken off so as to be vertical, and must be freed from dirt and properly wet before fresh concrete is laid against it. No carting, wheeling, walking or bicycle riding should be allowed on the concrete until it has hardened.

The top surface of all concrete foundations should be left rough so as to better hold the wearing surface which is placed upon it. Expansion joints may be left at intervals not over 100 feet lengthwise of the street. They can be made best by setting in the concrete a 1-inch board upright on its edge across the street from the curb to curb and after the concrete is sufficiently hardened the board is removed and the space filled with coarse or fine gravel. Expansion joints are especially necessary near a change in grade of the street where expansion from heat may cause the pavement to buckle upward.

CROWNING OF ROADWAYS.

The finished surface of all roadways should be higher at the center than at the gutters to afford good drainage. Although engineers do not entirely agree as to the proper amount of this crowning, practically all agree that the upper surface of the sub-grade and of the foundation should be crowned to conform to the upper finished surface of the street pavement. Crowning is necessary on all streets and for all materials and the smallest crown which will properly drain the street surface is best.

The top of the sub-grade is always below the surface of the finished pavement by an amount equal to the thickness of the pavement and its cushion, if any, plus the thickness of the concrete foundation.

In addition to crowning of the surface the street should have a longitudinal grade so that water can be carried off. This grade should not be less than 0.3 feet or 4 inches in 100 feet for hard materials such as pavements of concrete or good macadam. Where the street is level the longitudinal drainage must be secured by giving a grade to the gutters between catchbasins. This necessitates varying the crown along the street.

For widths of roadways between curbs of 24, 30, 36, 48, and 60 feet the crown should be 3, 4, 5, 6, and 8 inches respectively; the inches given being the difference in elevation of the finished wearing surface at the center of the street and at each curb.

The cross section of the street surface is curved and points on this curve can most easily be located by driving stakes at the center of the street, at each curb and at points $\frac{1}{3}$ and $\frac{2}{3}$ distant from the center to the curb on either side. The tops of these stakes can be located in the following manner: Stretch a string across the street so that it will be level at the proper elevation of the upper finished surface of concrete foundation at the center of the roadway. Compute the ordinates from the string to the elevation of the finished surface of foundation at points $\frac{1}{3}$ and $\frac{2}{3}$ of the distance from the center toward each curb. The ordinate to be measured down at the $\frac{1}{3}$ point nearest the center is equal to $\frac{1}{9}$ of the amount of crown determined upon and the ordinate to be measured down at the $\frac{2}{3}$ point from the center is $\frac{4}{9}$ of the total crown. This is illustrated in the accompanying table. Thus,

TABLE OF OFFSETS FOR CROWNING STREETS OF VARIOUS WIDTHS.

Width of Roadway Between Curbs		Distance From Center of Roadway	Vertical Offset		Distance From Center of Roadway	Vertical Offset	
Feet	Inches		Inches			Inches	
24	3	4	$\frac{1}{3}$		8	$1\frac{1}{3}$	
30	4	5	$\frac{4}{9}$		10	$1\frac{7}{9}$	
36	5	6	$\frac{5}{9}$		12	$2\frac{2}{9}$	
48	6	8	$\frac{2}{3}$		16	$2\frac{2}{3}$	
60	8	10	$\frac{8}{9}$		20	$3\frac{5}{9}$	

for a roadway 24 feet wide having a crown of 3 inches the elevation of the finished surface of foundation at points 4 feet on either side of the center should be $\frac{1}{9}$ of 3 inches, that is, $\frac{1}{3}$ inch below the level string, which corresponds with the elevation of the upper surface of concrete foundation at the center. At points 8 feet out on either side of the center of the roadway the elevations of the finished surface of foundation should be $\frac{4}{9}$ of 3 inches, or $1\frac{1}{3}$ inches, below the string. The gutter of course would be 3 inches below the surface at the center where the crown is 3 inches as here assumed. The grade of the sidewalk next to the property line is frequently made the same as the center of the street.

Transverse rows of stakes similar to those just described are placed every 10 to 25 feet apart lengthwise of the street. Of course, these stakes should be driven in after the sub-grade is thoroughly rolled and shaped so that they will be parallel to the finished surface of street.

The curbs should always be set to line and grade before the foundation for the pavement is laid.

FOUNDATIONS UNDER STREET RAILWAY TRACKS.

When a street or a portion of a street under improvement is occupied by street railway tracks and the tracks are removed during construction work, the excavation of that portion of the street occupied by the tracks should be made to a depth of 6 inches below the bottom and 6 inches beyond the ends of the ties. The remainder of the excavation must correspond in depth to that required for the ordinary pavement. The concrete along the track is then laid to a thickness of 6 inches below the bottom of the ties. The ties and rails are set in place upon this layer and brought to true line and grade. Additional concrete should be tamped under and around the rails and thoroughly grouted with a grout made of 1 part "ATLAS" Portland Cement to 2 parts clean, sharp sand. In case concrete beam construction is used, that is, where a rectangular beam of concrete is laid longitudinally under each rail, the excavation must conform to special plans for the track construction.

For sheet asphalt pavements the top of the concrete foundation should be parallel with and 3 inches below the finished surface grade. For stone block pavements to allow for 6-inch block and 2-inch sand cushion the top of the concrete is 8 inches below the finished surface of the pavement. Brick pavements are usually 4 inches thick and are laid with a 2-inch sand cushion between the bottom of bricks and top of concrete foundation so that the concrete is 6 inches below the finished grade.

CONCRETE PAVEMENTS.

The use of concrete for the wearing surface of a pavement as well as for the foundation is comparatively recent. The examples of these pavements already built have proved so successful that the increase in this class of construction will undoubtedly be very rapid. If, as has been indicated, proper care is used in the selection of the materials and in the workmanship, such pavements will prove satisfactory and durable.

Concrete pavements have been successfully built by several cities as described in the pages which follow, and patented types of pavement, the Blome and the Hassam, have also been laid in various places. Pavements built in Richmond, Ind., and other cities, have been made by similar methods to those employed for first-class sidewalk construction, using a compacted and well drained foundation of concrete and a mortar wearing surface. The Blome pavement is similarly made with a concrete foundation and a concrete wearing

surface, using specially selected materials and having the surface divided into blocks. The Hassam pavement usually consists of well compacted layers of broken stone with the voids filled with Portland cement grout and thoroughly rolled.

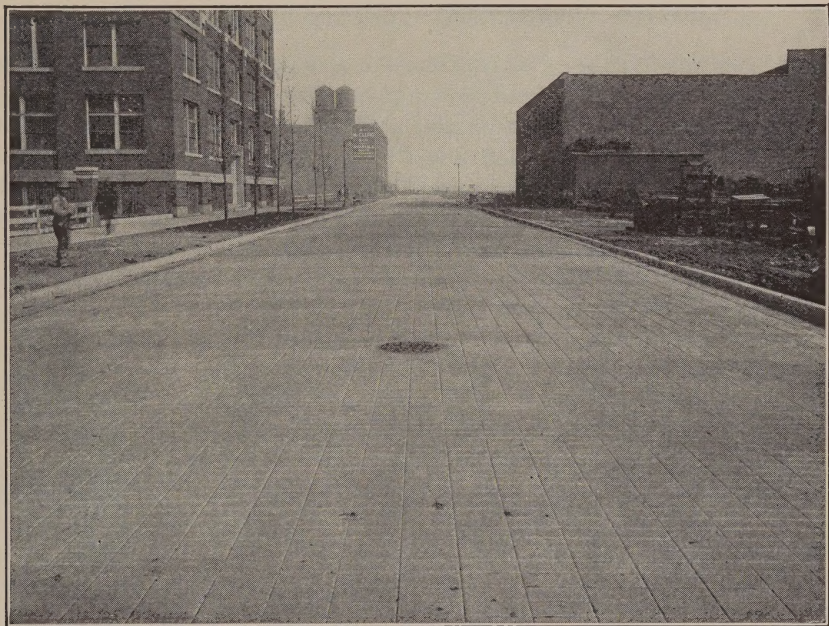


FIG. 15.—BLOME GRANITOID PAVEMENT, OHIO STREET, CHICAGO.

ESSENTIALS OF A CONCRETE PAVEMENT.

In order that a concrete pavement shall prove satisfactory the following essentials must be adhered to:

- (1) Thoroughly compacted sub-foundation.
- (2) Foundation (unless the soil is very porous) of porous materials rolled or otherwise compacted.
- (3) A base of first-class Portland cement concrete.
- (4) A wearing surface composed of a standard Portland cement and a carefully selected aggregate.
- (5) Expert and very careful workmanship.

The fine aggregate for the surface layer is of the utmost importance. Perhaps the best material is crushed granite or crushed trap whose particles pass a $\frac{1}{4}$ -inch sieve and which contains scarcely any dust. Sand may be used pro-

vided it is of exceptionally good quality, coarse, clean, free from clay or other fine matter, and absolutely free from vegetable loam. In natural sand the percentage of dust passing a sieve having 100 meshes per linear inch might well be limited to 3 per cent.

BLOME CO. GRANITOID CONCRETE PAVEMENT.

Pavements made entirely of concrete are coming more and more into general use as the true strength and worth of concrete is becoming better known and understood. One of the all-concrete pavements is known as the Blome Co. Patented Granitoid Pavement and is laid under patents owned by the Rudolph S. Blome Company of Chicago. As previously stated the Blome Co. Granitoid pavement consists of a lower layer of concrete serving as a base and an upper thinner layer of richer concrete forming a wearing surface; the two layers being laid so as to secure a perfect union, thus forming a monolith. The upper surface is grooved to give a good foothold for horses.

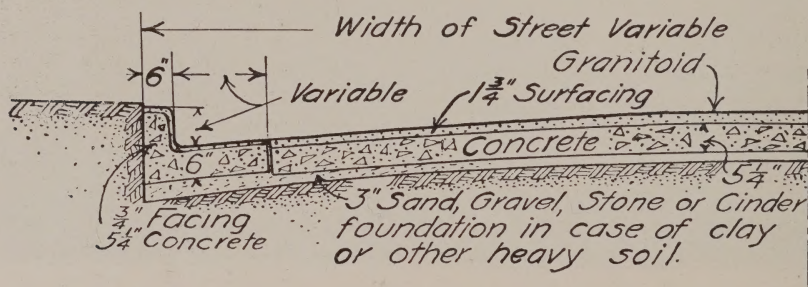


FIG. 15.—STANDARD SECTION BLOME CO. PATENTED GRANITOID PAVEMENT.

Fig. 16 shows a standard section of the Blome Co. Granitoid Pavement. It consists of a $5\frac{1}{4}$ -inch thickness of concrete with a $1\frac{3}{4}$ -inch surface of a richer concrete, the two layers being laid so as to give it thorough union. The drawing shows a foundation of sand, gravel, broken stone or cinders which is necessary where the soil is clay or hard pan or in fact in any soil except a porous sand or gravel. Expansion joints, $\frac{1}{2}$ inch wide, are left along the gutters or curbs.

The granitoid pavement has been laid in many places and has given very good satisfaction. It presents a gritty surface and affords an excellent foothold for horses. On wet slippery streets horses travel more freely and easily on the granitoid pavement than on other more smooth and equally hard pavements. Granitoid has been used successfully on 8 per cent grades at Knoxville, Tennessee; on streets in Michigan where the temperature falls at times

to 40 degrees below zero; and on streets in the South where the pavement is subjected to intense heat. Granitoid pavements have demonstrated that when properly laid concrete is not seriously affected by temperature.

GENERAL SPECIFICATIONS FOR THE BLOME COMPANY GRANITOID CONCRETE BLOCKED PAVEMENT.

The following general specifications have been furnished through courtesy of the Rudolph S. Blome Company of Chicago.

PREPARATION OF SUB-GRADE.—The street shall be graded (excavated or filled as the case may be) to sub-grade, including compacting and rolling by means of a heavy steam roller, and all slopes, contours and other shaping required in the finished pavement shall be formed and provided for in said sub-grade, so that the foundation and pavement hereinafter specified will be uniformly of the same thickness throughout. The contractor to use extreme care to remove all spongy material or other unsuitable or vegetable matter that may be in the way of making this improvement a permanent one.

The contractor will bid with the strict understanding that he or they must use all necessary precautions in preparing the sub-grade, so as to support the pavement permanently, and so that the pavement shall remain at the original grade for a period of five years. This clause shall not be waived on account of any trenches or holes dug in the street by any corporation or private party, prior to the laying of the pavement.

FOUNDATION.—Where the natural soil is of sandy or gravelly nature, no other foundation will be required, but where the natural soil is clay, the contractor shall grade for and provide a foundation of sand, gravel, crushed stone or other suitable material, and which foundation after having been flooded and compacted, satisfactory to the engineer, shall be not less than 3 inches thick.

MATERIALS.—Samples of the cement which is proposed to be used in the work shall be submitted to the engineer in such quantities and at such time and place as will enable him to make all required tests.* The engineer reserves the right to reject without recourse any cement which is not satisfactory, whether for reasons mentioned in these specifications or for any good and sufficient cause.

All the cement to be used must be delivered on the work in approved packages, bearing the name, brand or stamp of the manufacturer. It shall be thoroughly protected from the weather until used in such manner as may be directed.

SAND.—All sand shall be clean, dry, free from dust, loam and dirt, of sizes ranging from $\frac{1}{8}$ inch down to the finest, and in such proportions that

*Specifications for the cement are also included.

the voids, as determined by saturation, shall not exceed 33 per cent of the entire volume, and it shall weigh not less than 95 pounds per cubic foot. No wind drifted sand shall be used.

CRUSHED STONE.—All crushed stone used in making the concrete shall be of the best quality of limestone, trap rock or granite, clean, free from dirt, broken so as to measure not more than $1\frac{1}{2}$ inches and not less than $\frac{1}{4}$ inch in any dimension. The stone when delivered on the street shall be deposited on flooring and kept clean until used.

GRAVEL.—If gravel is used, same to be perfectly clean gravel, free from all loam and foreign substances, and the same size as that specified herein for crushed stone.

MIXING AND LAYING OF CONCRETE AND FORMATION OF THE BLOME COMPANY GRANITOID BLOCKING.

The concrete and blocking hereinafter specified shall be constructed and manipulated according to the Blome Company patents and processes, using materials mixed in the proportions and laid as hereinafter specified.

The pavement shall consist of $5\frac{1}{4}$ inches of concrete, and surface blocking $1\frac{3}{4}$ inches, making a total of 7 inches, exclusive of foundation.

After the sub-grade and foundation have been prepared as hereinbefore specified, there shall be deposited concrete composed of 1 part of Portland cement, 3 parts sand, and 4 parts of crushed limestone, trap rock, or clean gravel. These materials to comply with the requirements hereinbefore set forth and shall be mixed by special mixing machine suitable for the purpose to be approved by the engineer and shall be mixed at least five times before being removed from the mixer. The concrete shall be thoroughly tamped in place, and shall be $5\frac{1}{4}$ inches thick, uniformly at all points, after having been compacted, shall be laid in sections with expansion joints, all as per the Blome Company patents and shall follow the slopes of the finished pavement so that the surface blocking is and shall be uniformly of the same thickness at all points.

SURFACING MATERIAL.—After the concrete has been placed and before it has begun to set, there shall be immediately deposited thereon the Granitoid Blocking which shall be $1\frac{3}{4}$ inches in thickness to be composed of two parts of the hereinbefore specified Portland cement and three parts of clean, crushed granite, trap rock, hard stone, crushed gravel, crushed boulders, or other similarly hard materials shall be screened with all the dust removed therefrom utilizing the following composition of this material.

Fifty per cent of the granite, trap rock, hard stone, crushed gravel, crushed boulders or other similarly hard materials to be what is known as $\frac{1}{4}$ -inch size,

30 per cent of the $\frac{1}{8}$ -inch size, and 20 per cent of the 1-16-inch size with all finer particles removed. These proportions of sizes are extremely essential and must be kept absolutely accurate as in this lies one of the essential requirements to produce proper results. This material to be mixed with cement thoroughly and after being wetted to a proper consistency and deposited on the concrete shall be worked into brick shapes of approximately $4\frac{1}{2}$ inches by 9 inches with rectangular surface similar to paving blocks, all as per special method and utilizing grooving apparatus as employed under the Blome Company patents. The pavement shall be sloped in a manner as required by the City Engineer.

Should there be any part or parts of this pavement when completed where the slopes, contours, etc., have not been carried out in true manner then under this specification the contractor will be required to take up such part or parts down to the foundation and replace same to the proper level without expense of any kind to the city.

EXPANSION JOINTS.—The contractor for the work above specified shall also be required to provide for expansion joints across the pavement at such locations as may be necessary, which expansion joints shall extend through the blocking and concrete and shall be filled with a composition especially prepared for the purpose according to the Blome Company patents. These expansion joints shall be constructed in an extremely careful manner under specific direction of the City Engineer.

PATENTS.—All fees for any patent invention, article or arrangement or other apparatus that may be used upon or in any way connected with the construction, erection, or maintenance of the work or any part thereof, embraced in the contract on these specifications shall be included in the price stipulated in the contract for said work, and the contractor or contractors must protect and hold harmless the city against any and all demands for such fees or claims.

GUARANTY.—Upon the completion of the contract, the contractor shall furnish a satisfactory surety company bond executed by one of the Surety Companies in good standing in the State of _____, guaranteeing the pavement mentioned against settlements, upheavals, disintegration and the results of faulty workmanship, and the use of materials of improper quality for and during the period of five years from and after the date of completion of the pavement.

It is to be expressly understood that the above-mentioned pavement shall satisfactorily withstand all severe usage to which same will be subjected during and for the period named above.

BIDDERS' ATTENTION.—The attention of the bidders is called to the following copy* of agreement in the offices of the City Clerk for furnishing

*Not here given.

necessary materials and mixtures for laying the surfacing material of the contemplated pavements and for the allowance of the uses of certain patented processes owned and controlled by the Blome Company and for the expert advice which will be furnished, which agreement forms a part of these specifications and which must be considered as a requirement by prospective bidders in the making up of their proposals on the contemplated work.

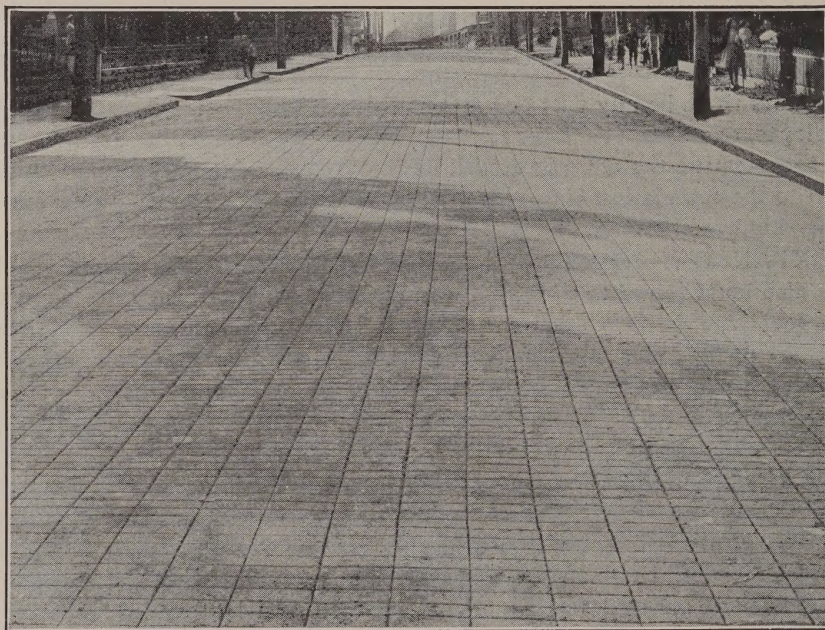


FIG. 17.—BLOME CO. GRANITOID PAVEMENT, KNOXVILLE, TENN.

COST OF BLOME CO. GRANITOID PAVEMENT.

The cost of this pavement varies greatly, depending upon location, quantity of work, costs of the various materials and labor. The price ranges from \$1.50 to \$3 per square yard, not including excavation or grading. Its use compares favorably in cost with brick, asphalt, or creosote or wooden blocks on concrete foundations.

In Knoxville, Tenn., the same granitoid laid in accordance with methods previously described cost \$1.88 per square yard in place, exclusive of the grading, which varied from 15 to 20 cents per square yard of pavement, making the total cost of finished pavement from \$2.03 to \$2.08 per square yard.

In New Haven, Conn., the Blome pavement has been laid at \$2.25 per square yard.

A piece of granitoid block laid on 48th Avenue, Hawthorne, Ill., in the fall of 1904, was in very good condition when examined in January, 1909. This pavement is 7 inches thick and cost \$3 per square yard exclusive of excavation or grading.

HASSAM PAVEMENT.

Hassam pavements are laid in the form of a grouted macadam street or as a granite block pavement on a grouted macadam foundation. In each case the work is done in a manner peculiar to this type of pavement.

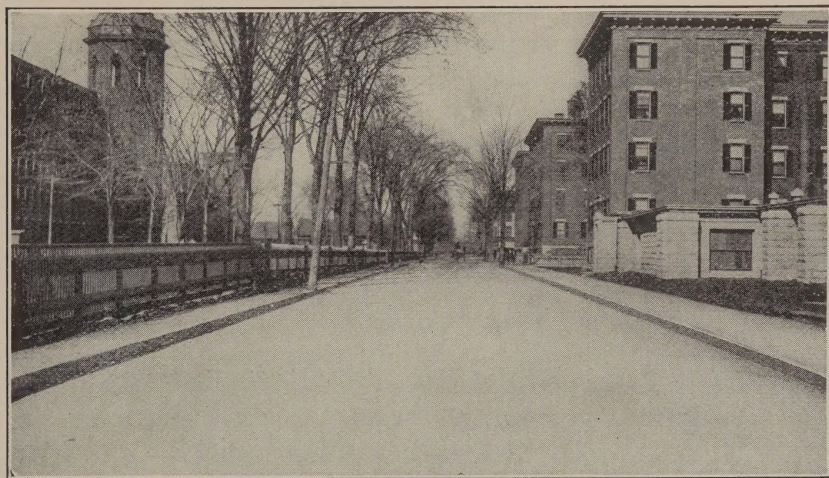


FIG. 18.—HASSAM PAVEMENT, BIDDEFORD, MAINE.

HASSAM GROUTED CONCRETE PAVEMENT.

The Hassam pavement as usually laid consists of a properly compacted sub-grade upon which is placed a layer of broken stone thoroughly rolled to a thickness of six inches and made to conform to the grades and contour of the street. After this stone has been firmly compacted by rolling and the voids reduced to a minimum it is grouted with a Portland cement grout made of one part cement and two parts sand. This grout is poured upon the stone until all the voids are filled and the grout flushes to the surface. The rolling is continuous during the process of grouting. Upon this surface is placed a very thin layer of pea stone which is spread over the entire area of the roadway, grouted and rolled, the rolling to continue until the grout flushes to the surface. Expansion joints are left along the curbs. The data given above was taken from the specifications of the Hassam Paving Company who have a patent on this pavement.

Hassam pavement has been laid upon a grade of 7 per cent in Biddeford, Maine.

LONG ISLAND MOTOR PARKWAY.

The automobile is rapidly changing the conditions governing the building of improved streets and highways. This is particularly noticeable along the suburban highways where it is possible to run automobiles at high speeds. Concrete pavement seems to be well adapted to meet the conditions imposed by this particular class of traffic. An example of the Hassam type of pave-



FIG. 19.—CONSTRUCTION OF LONG ISLAND MOTOR PARKWAY.

ment for automobile traffic is the Long Island Motor Parkway. The paved portion of this parkway is several miles in length and "ATLAS" Portland Cement was used throughout.

The method of construction was as follows: The sub-grade was shaped and rolled with a 10-ton roller. A $2\frac{1}{2}$ -inch layer of broken stone $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in size was then spread upon the sub-grade and upon this broken stone a wire fabric reinforcement was laid over the entire width of the roadway and the separate sheets overlapped as shown in the photograph. A layer

of broken stone was then spread upon the fabric so as to conform to the cross section of the roadway and to give a pavement five inches in thickness after rolling.

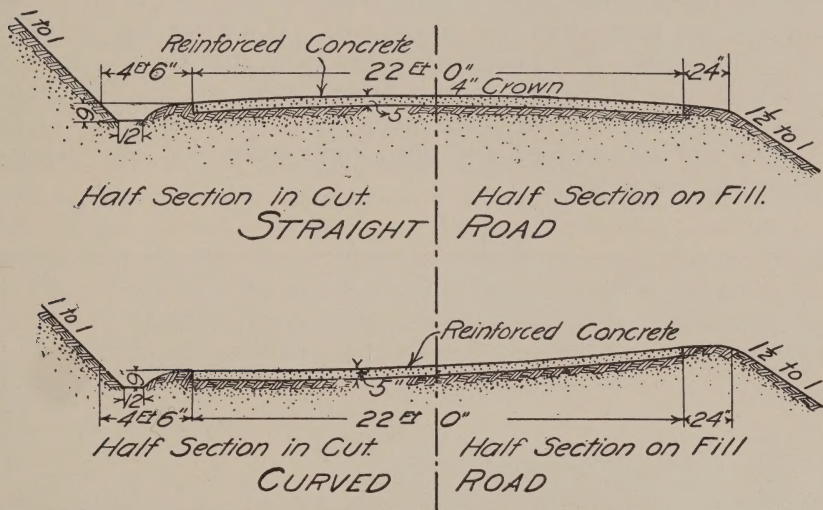


FIG. 20.—TYPICAL CROSS SECTION OF LONG ISLAND MOTOR PARKWAY.

After the ballast was placed on the reinforcement it was thoroughly rolled and compacted with a 10-ton roller. Portland cement grout made with one part of "ATLAS" Portland Cement and two parts sand was mixed in a mechanical mixer and poured upon the surface of the rolled ballast until all the voids were filled and until the grout flushed to the surface after rolling. The grout was colored with lampblack to slightly darken the finished pavement. After the grout had been poured and rolled a thin layer of pea stone was spread, grouted, and the surface again rolled as before.

The finished pavement was given a rough surface by brooming so as to form very small ridges at right angles to the length of the roadway. Care was taken to complete all rolling after grouting each section before a sufficient period of time had elapsed to allow the cement to take its initial set. Automobiles were allowed on the finished pavement ten days after completion.

This pavement was laid by the Hassam Paving Company of Worcester, Mass. No provision was made for expansion or contraction, but as previously stated the roadway was reinforced with wire fabric. Fig. 20 shows typical sections of the parkway. The upper drawing represents construction where the road is straight, and the lower where the road is on a curve.

COST OF HASSAM PAVEMENT.

A Hassam pavement was completed in Watertown, Mass., during October, 1908, at a cost of \$1.85 per square yard. The pavement consists of a 6-inch thickness of rolled broken stone grouted with one part "ATLAS" Portland Cement and two parts clean, fine, sharp sand. The grout was mixed in a Hassam grout mixer. The surface of broken stone after the first grout was placed was covered with a pea grade of broken stone, and this finer stone in turn was covered with a grout of the proportion of one part "ATLAS" Portland Cement and one part sand, and rolled with a steam road roller before the first grout had time to set.

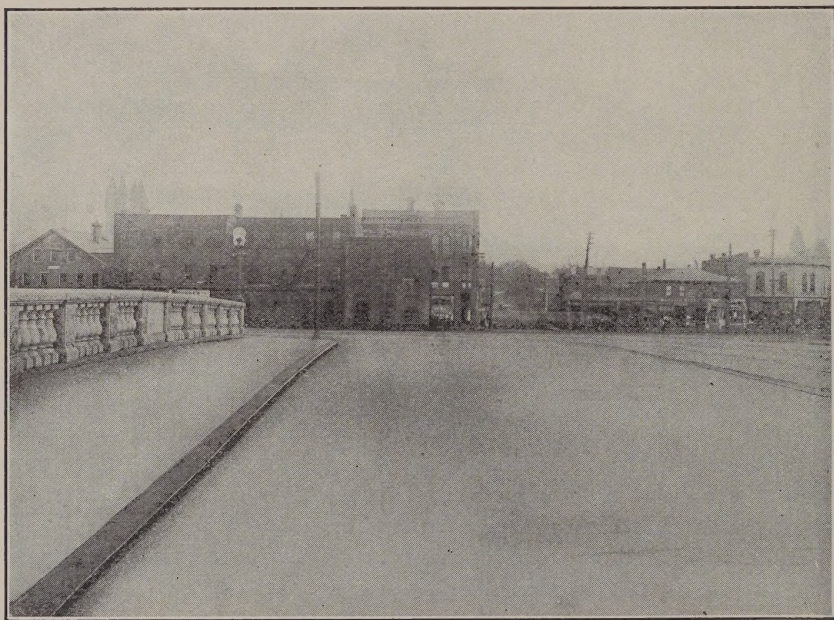


FIG. 21.—HASSAM PAVEMENT, WATERTOWN, MASS.

HASSAM GRANITE BLOCK PAVEMENT.

River Street, in Troy, N. Y., is paved with a Hassam Granite Block Pavement on a Hassam foundation. The foundation in this pavement consists of a 6-inch layer of broken stone grouted with one part "ATLAS" Portland Cement and four parts sand. Grout was mixed in a Hassam grout mixer, was poured upon the broken stone until all voids were filled and the grout flushed

to surface. This foundation was rolled during the process of grouting as well as being thoroughly compacted by rolling before the grout was applied.

The pavement proper consists of granite paving blocks having dimensions 4 to 4½ inches deep, 3½ to 4½ inches wide and 6 to 12 inches long, laid on edge across the street on a sand cushion 1½ inches in thickness placed on the Hassam foundation. Pea stone was sprinkled upon the surface of the blocks and swept into the joints with wire brooms, the pavement rolled to an even surface or rammed when roller could not be used, and the surface was then swept clean and the joints filled with a grout made of one part "ATLAS" Portland Cement and one part clean, sharp sand. The grout was spread upon the paving and brushed into the joints, the stone blocks having previously been wet by sprinkling, and the grout was then broomed to a fine smooth surface. The blocks were laid with joints not to exceed ½ inch.

The sand cost \$1.25 per cubic yard delivered upon the street in bags. Crushed stone cost \$1.45 per cubic yard delivered. Day labor cost \$1.75 per day of 8 hours. Contract price including all materials and labor was \$3 per square yard. Fig. 22 shows a cross section of this street.

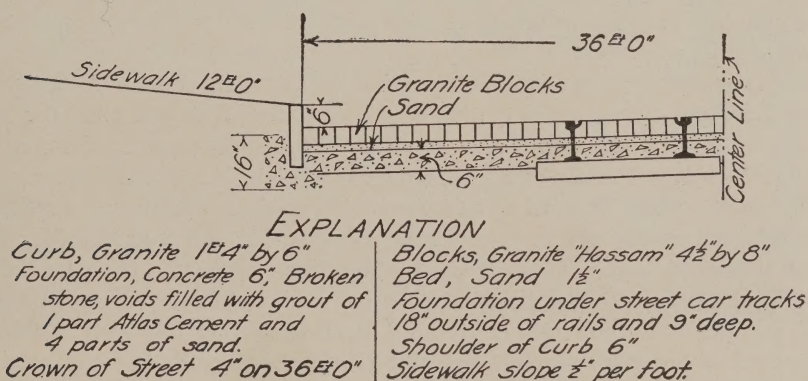


FIG. 22.—CROSS SECTION OF GRANITE BLOCK PAVEMENT ON RIVER STREET, TROY, N. Y.

CONCRETE PAVEMENT IN RICHMOND, IND.

Numerous streets and alleys have been paved with concrete in Richmond as previously stated in this chapter. The first concrete street pavement in Richmond was laid in 1896 at a cost of \$1.62 per square yard, since then the cost has been still further reduced.

The usual pavements for streets of ordinary traffic in Richmond have a concrete base 5 or 6 inches thick with a top wearing surface 1 or 1½ inches thick.

For such pavements, that is, those requiring a thickness of 6 or 7 inches, a foundation consisting of 8 inches of rubble, field cobble stone, the refuse from quarries, or coarse gravel is placed. On this layer is spread sufficient gravel to fill the spaces, and, after flooding and ramming, to make a total thickness of the foundation of 10 inches.

On this foundation 5 inches of thoroughly rammed 1:2:5 concrete is laid in blocks 10 feet by 15 feet.

The wearing surface, 1½ inches in thickness, and composed of one part cement and two parts clean, coarse sand; or else of one part cement, one part sand, and one part clean, crushed stone screenings, must be placed on the 5-inch base before the latter has set. This wearing surface is troweled down to insure contact, then leveled off with a straight edge. When hard enough it is floated or troweled to a smooth, continuous surface.

The surface is finally pitted with a brass roller except for marginal strips two inches wide around the edges of the blocks. The wearing surface is cut into blocks the same size as the base.

For streets having heavy traffic a concrete base is laid in addition to the regular pavement so that the total thickness is the same as a brick pavement on a concrete foundation or about eleven inches total. These pavements are constructed as follows:

Where necessary an 8-inch layer of gravel thoroughly wet and consolidated is used for sub-drainage and upon this gravel foundation is placed a 6-inch layer of 1:3:6 Portland cement concrete. When this concrete foundation is strong enough to sustain the roadway pavement it is covered with a coating of fine sand, raked off with a flat board rake so as to remove all sand except that which may remain in low places and voids in the concrete foundation. Upon this sand is placed a thin layer of tar paper and upon the paper a 1:2:5 concrete layer four inches thick.

Upon the above concrete is placed a wearing surface one inch in thickness composed of one part cement, one part clean, sharp sand, and one part clean stone or granite screenings, mixed with water to form a rather wet facing mixture. In some cases this wearing surface is placed in two layers, each one-half inch thick, the first to be thoroughly rammed to insure perfect contact; the second applied immediately after and troweled and worked over, and made to conform to the finished surface of the street. When sufficiently hard, the surface is floated and steel troweled and finished with a cork float.

CONCRETE PAVEMENTS IN THE CITY OF PANAMA.

Fig. 23 shows West Fifteenth Street in the city of Panama being paved with 1:2½:5 "ATLAS" cement concrete five inches thick; after tamping in place it is finished with a straight edge and trowel. The surface is smooth but

not slippery. The concrete, hand mixed, was placed with wheelbarrows. Broken stone was obtained by crushing old cobble stones. The sand was obtained from Panama Beach. In 1906 and 1907 over two miles of this pavement was laid in the city of Panama at a cost of \$2 per square yard on streets having grades as high as 8 per cent. It was laid in alternate blocks or sections about 10 feet long lengthwise of the street and extending all of the way or one-half way across the street between curbs. The streets vary in width from 13 feet to 20 feet between curb lines.



FIG. 23.—CONCRETE PAVEMENT IN THE CITY OF PANAMA.

GROUTING STONE BLOCK AND BRICK PAVEMENTS.

For filling the joints in stone block or brick pavements the cement grout should be mixed one part "ATLAS" Portland Cement and one part clean sand with enough water to make the grout flow easily. The materials must be thoroughly mixed with hoes in a tight box at the place of using. As soon as the mixing is completed the grout must be immediately poured out of the box upon the surface of the pavement and broomed into the joints before the cement sets.

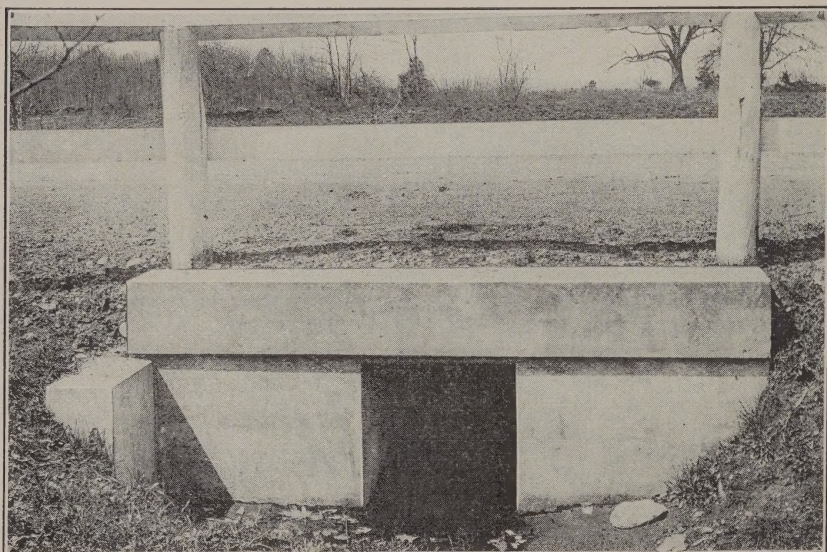
Every twenty-five feet, measured lengthwise of the street, one or two transverse joints should be filled with tar to provide for expansion. The joint next to each curb should also be filled with tar.

CHAPTER IV.

SEWERS, DRAIN TILES, BROOK LININGS, CONDUITS.

SEWERS.

While formerly all large sewers were built of brick and the smaller ones of vitrified clay or cast-iron pipe, in recent years concrete has entered this field of construction and through a process of expansion and adaptation has been



BOX CULVERT, AMHERST, MASS.

gradually supplanting all of these materials. At first its use was limited to foundations and the lower part of side walls, then to lining the invert of brick sewers, and finally increasing experience and additional confidence has led to its use for the construction of entire concrete sewers and also sewer pipes.

The larger concrete sewers, molded in place, are practically monolithic, while the smaller ones, constructed by joining short lengths of concrete pipes together and sealing the joints, make one continuous pipe.

Aside from being generally cheaper than brick, concrete sewers are more permanent and water-tight, have a much smoother surface and therefore a greater carrying capacity, and are less liable to damage and collapse through excessive loads, vibrations and unsuitable foundations.

CONCRETE PIPE SEWERS.

While monolithic sewers molded in place are entirely satisfactory for diameters of more than 30 inches, owing to the difficulty of devising suitable forms they are impractical and less economical for smaller diameters. Concrete pipe, on the other hand, can be made economically and easily in sizes ranging from 3 inches to 36 inches inside diameter.

Concrete pipes can be made wherever gravel, sand and cement can be brought together, and at a cost considerably lower than cast-iron pipe and usually less than vitrified clay. They can be molded as desired into sectional forms which are more conducive to stability and efficiency than the circular cross-section which is necessary with cast iron or vitrified clay. By giving concrete pipe a broad, flat level base, they are made to rest firmly and securely on a continuous, flat earth foundation, while to secure such a bearing for a circular pipe requires tamping the earth filling into the space beneath the two sides of the pipe and also cutting out a depression in which the bells can rest.

In localities where there are great variations in the amount of sewage flowing through the pipes an oval form of cross section is better than a circular one. For this concrete must be used, since vitrified pipe cannot be made into these forms on account of the warping due to burning.

This warping also prevents the finished section of vitrified pipe from being truly circular so that when these pipes are fitted together there are rough projections at many points on the inside of the pipe which tend to collect solid matter in the sewage and thus to reduce its carrying capacity.

Concrete pipes can be given a tapering butt joint, instead of the bell and spigot joint common for vitrified and cast-iron pipe, which considerably re-

TESTS OF PLAIN CONCRETE SEWER PIPE IN BROOKLYN.

Kind	Diameter, Inches	Thickness, Inches	Age	Breaking Load, Lb. per Lin. Ft.
A	12	1 $\frac{3}{16}$	 32 days	1,689
B	15	1 $\frac{7}{16}$	 33 days	1,800
B	18	1 $\frac{3}{8}$	 29 days	1,767
A	12	1 $\frac{3}{16}$	 1 month 29 days	1,622
B	15	1 $\frac{1}{2}$	 2 months 3 days	1,617
B	18	1 $\frac{7}{16}$	 1 month 29 days	1,522
C	6	1 $\frac{5}{16}$		2,600
A	9	1 $\frac{3}{16}$	Several years over 3 years	2,011
A	12	1 $\frac{1}{4}$	2 years 9 days	1,983
B	15	1 $\frac{1}{2}$	1 year 7 months 20 days	1,962
B	18	1 $\frac{5}{8}$	2 years 7 days	2,022
B	24	2 $\frac{1}{8}$	2 years 1 month 28 days	1,978

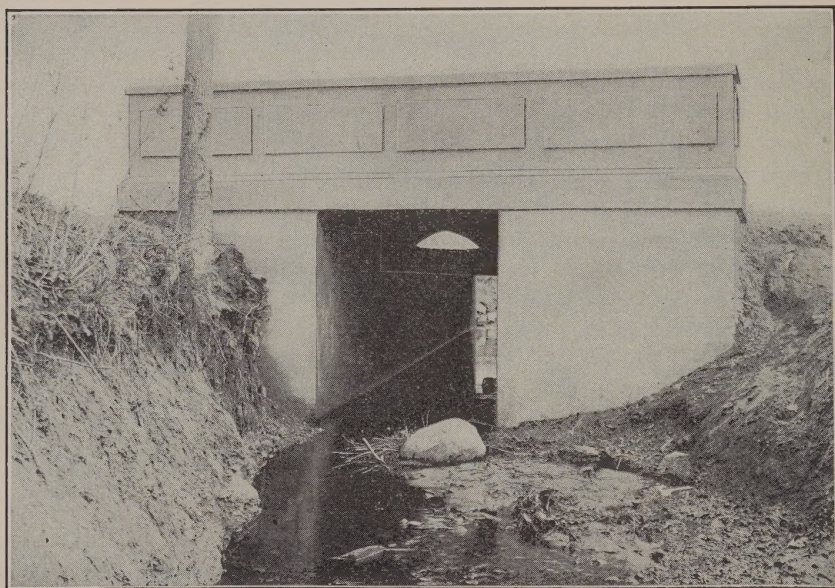
A, circular pipe with flat base. B, egg-shape with flat base. C, circular pipe.

*Part of table from Engineering Record, Vol. 58, Nov. 21, 1908, p. 591.

duces both the cost of manufacture and of joining the pipe with mortar in the trench.

That concrete pipes without reinforcement possess sufficient strength for use as sewers is shown in the accompanying table* which gives the results of tests on pipes made in the testing laboratory of the Bureau of Sewers of Brooklyn, N. Y.

The pipes which, as seen from the accompanying table, varied in diameter from 6 to 24 inches, were made of a mixture of $1\frac{1}{2}$ parts cement to 1 part sand to 3 parts trap rock screenings, and were tested at ages varying from twenty-nine days to over two years. The 6-inch pipes were made 24 inches long while the larger diameters were 36 inches in length. They were tamped into molds, and then subjected to heat to dry them immediately after molding,



CULVERT, DUMONT, N. J.

the forms being removed within half an hour after the work on a length was started.

In testing a section of the pipe it was laid on a sand bed so that the lower one-sixth of its circumference was in contact with the sand and then the pressure was applied from the testing machine along the upper surface of the pipe until the pipe broke. In order to secure an even distribution of the pressure along the length of the pipe, the pressure was applied through a strip of plaster of Paris one inch wide and not over one-quarter inch thick, held in place by strips of wood.

The accompanying table shows the sizes of the pipe in inches together with the thickness of the walls, the age, and the breaking load in pounds per linear foot. In order to break a 12-inch pipe 32 days old, for example, a load of 1,689 pounds on each foot of length of the pipe was required, the total load for the 3 feet of pipe being thus three times 1,689, or 5,067 pounds.

The pipes, it must be remembered, were of plain concrete without reinforcement.

LARGE CONCRETE SEWERS.

Large sewers and conduits are built of plain concrete and also of reinforced concrete. For diameters of 3 to 4 feet the thickness required for good construction is usually sufficient without reinforcement as they can be reckoned as strong as a brick sewer of the same diameter which is half again as thick. For large diameter, reinforcement is generally advisable, and the saving in material will more than counterbalance the added cost of reinforcing. The reinforcement adds to the strength of the sewer during construction, and when completed enables it to withstand a larger pressure after the earth is filled in around and on top of the pipe, and also renders it less liable to damage where there is danger of settlement.

THICKNESS OF CONDUITS*

Diameter of Conduit	Thickness of Crown, Inches	Thickness of Haunch, Inches	Thickness of Invert, Inches
2	4	6	5
6	7	18	8
12	13	23	14

"If reinforcement is used, the thickness for conduits for ordinary sizes is usually determined by the minimum thickness of concrete which can be laid so as to properly imbed the metal. This minimum for the large diameters where steel is advisable may be taken as 6 inches."

As a guide for determining the thickness of concrete required for both plain and reinforced concrete sewers, the general rule used by Mr. William B. Fuller* is given as follows:

"If concrete is not reinforced and ground is good—able to stand without sheeting—make crown thickness a minimum of 4 inches, and then one inch thicker than diameter of sewer in feet. Make thickness of invert same as crown plus one inch except never less than 5 inches. Make thickness at haunches two and a half times thickness of crown, but never less than 6 inches. If ground is soft or trench is unusually deep, these thicknesses must be increased according to experienced judgment."

SIZES OF CIRCULAR CONCRETE SEWER PIPE.

Fig. 24 shows one form of concrete circular pipes suitable for sewer con-

*See reference, footnote, page 18.

struction. The pipes are shown 2 feet 6 inches in length over all, the inside diameters can be anything from 12 to 48 inches, and the thickness of the pipe from 2 to 6 inches. The joints are beveled so that when laid with Portland cement mortar the joints will be practically water tight, and will present a smooth surface so that solid matter will not be deposited, as is apt to be the case in vitrified pipe sewers.

In laying these pipes a little mortar mixed 1 part "ATLAS" Portland cement and 2 parts clean sharp sand is placed inside of the pipe in the inner beveled surface. The pipe is then pushed hard against the beveled end of the length of pipe already laid, and the mortar smoothed off inside and outside of the pipe so as to make a smooth joint.

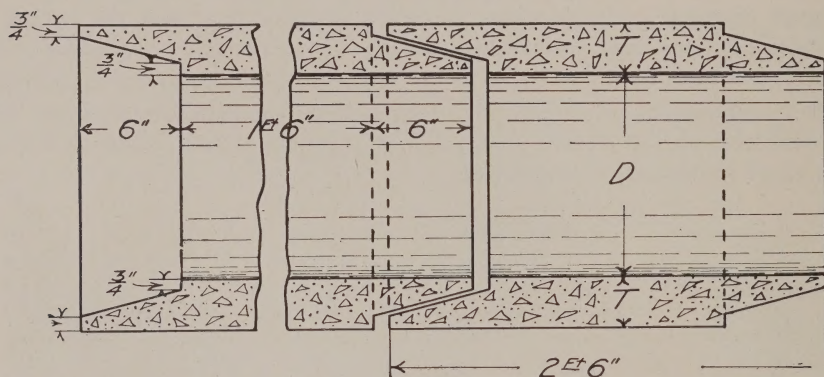


FIG. 24.—LONGITUDINAL SECTION OF SEWER PIPES.

The inside diameter of the pipes, D in Fig. 24, are 12, 18, 24, 30, 36, 42, and 48 inches, and the thickness T in the figure corresponding to these diameters should be 2, 3, $4\frac{1}{4}$, $4\frac{1}{2}$, $4\frac{3}{4}$, $5\frac{3}{4}$, and 6 inches. That is, for a 12-inch pipe the thickness should be 2 inches; for an 18-inch pipe, 3 inches, and so on. For drain tile, which need not be so thick as sewer pipe, thinner pipe may be used.

PROPORTIONS OF CONCRETE FOR SEWER PIPE.

Concrete used in the construction of sewer pipe, that is, in the construction of pipes having diameters of 12 or more inches, should be mixed in the proportions of 1 part "ATLAS" Portland Cement, 2 parts clean, sharp sand, to 4 parts crushed stone or clean coarse gravel not more than 1 inch in diameter.

CONCRETE DRAIN TILE.*

Tiles are used for draining roadways and farms.* A roadway of even the best material needs some drainage and for roadways made of poor materials drainage is absolutely essential. Concrete drain tiles are the best for the under drainage of any roadway or sidewalk. Oftentimes in the construction of roads and sidewalks one or more longitudinal lines of drain pipes are laid underneath the surface of the road or sidewalk and at convenient places are carried to proper outlets. Frequently a drain 4 inches in diameter is sufficient for draining sidewalks or roadways.

SIZE OF CONCRETE DRAIN TILES.

Concrete drain tiles are made in sizes of 4 inches to 30 inches inside diameter. Ordinarily the sizes from 4 to 12 inches are molded by machine, although they may be made in simply constructed molds as described in "Concrete Construction about the Home and on the Farm," while the larger sizes are usually made by hand. Although concrete sewer pipes have either bell shaped or other similar joints, concrete drain tiles are nearly always made with plain ends.

The thickness of the shell for tiles varies from 1 inch or even thinner for the 4-inch pipes to 3 inches for the 36-inch pipes. The sizes under 10 inches in diameter are made 1 inch or less in thickness; the 12 to 24-inch, from 1 to 2 inches thick; the 24 to 36-inch, 3 inches.

Usually sizes under 10 inches in diameter are made 18 inches long and those 10 inches or more are made 2 feet long.

MIXTURES FOR TILES.

The best mixture for tiles is 1 part "ATLAS" Portland Cement to 3 parts clean coarse sand, or sand and gravel passing a $\frac{1}{2}$ -inch screen.

A 1:3 mixture for drain tiles to be used in roads, either for longitudinal or cross drains, gives the proper strength to the pipes. For farm drainage and other similar locations where there is not much pressure exerted upon the pipe a 1:4 mixture is sometimes used.

CURING.

For ordinary drain tiles the concrete should be mixed with enough water so that the moisture will show at the surface when the concrete is tamped. As a general thing, the molds can be removed as soon as the concrete is thor-

*See also "Concrete Construction about the Home and on the Farm," p. 91. This book may be obtained by writing to The Atlas Portland Cement Co., New York.

oughly rammed into them. After the molds are removed, the tiles should be placed in the shade, and wet down as soon as the concrete will stand the water without washing, which is ordinarily from 8 to 10 hours after molding. It is of the utmost importance that they should not be allowed to dry out for at least 4 days, and they should also be kept in the shade for 8 or 10 days, being wet once or twice each day during this period. If the weather is very dry or hot, 3 or 4 wettings for the first few days are desirable. A pretty good rule to follow is that the pipes must not be allowed to dry "white" until they are at least 8 days old. After this treatment the tiles should be stored in an open

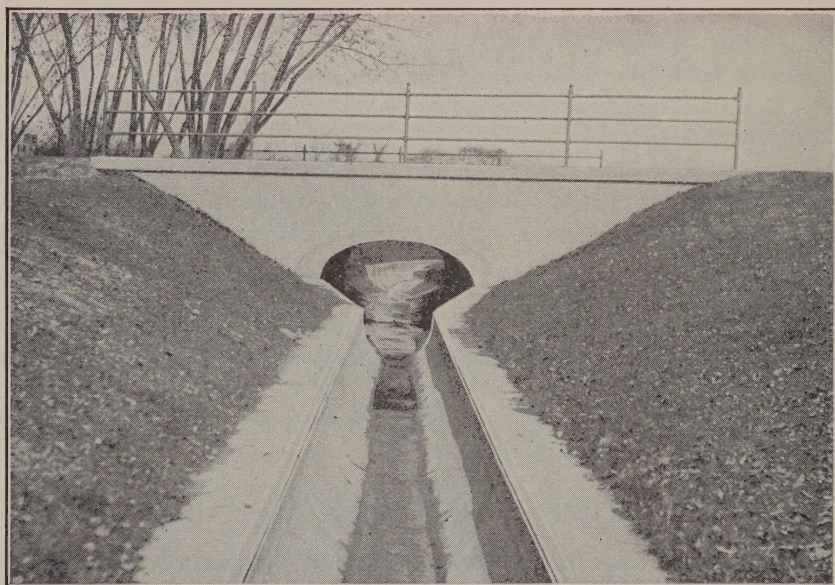


FIG. 25.—CONCRETE BROOK LINING IN NEWTON, MASS.

yard to season and harden. In ordinary weather the pipes are ready for shipment in 30 days.

LAYING DRAIN TILES.

Concrete drain tiles under roads must have at least 1 foot of earth on the top of the pipe and they must be laid on a grade of at least 1 foot in 100 feet, that is, one foot fall of the pipe in 100 feet of distance.

The pipes should be laid with open joints, that is, with the ends simply abutting without any mortar.

BROOK LININGS.

A small stream of water running through a town or through the flats adjoining a town often is the cause of a great deal of trouble. If the adjoining lands are to be divided into house lots the brook must be properly taken care of. Usually the best solution for this problem is to change the course of the brook so that it will flow under a street through a concrete conduit. If the stream is not within the limits of a street the banks can be lined with

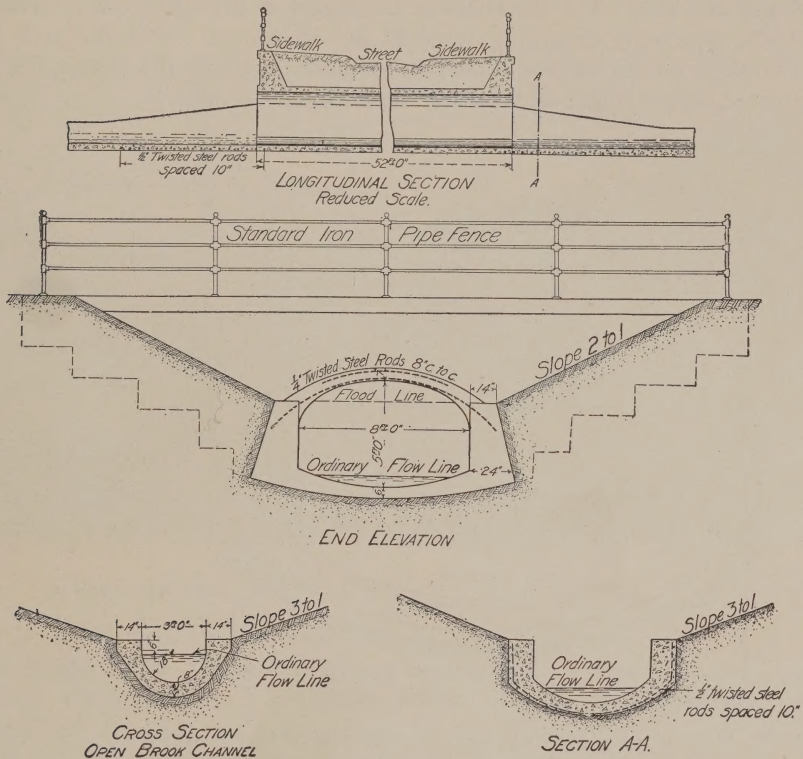


FIG. 26.—CONCRETE BROOK LINING IN NEWTON, MASS.

concrete, the top thus being left open. The concrete lining prevents the nuisance caused by the breeding of mosquitoes and other insects along the edges of the open brook. Fig. 26 shows typical drawings of a brook lining in Newton, Massachusetts. The concrete lining, throughout most of the length is curved to a radius of 18 inches, inside diameter, and for the most part is 8 inches in thickness, the invert being 8 inches and the thickness at the upper

surface of the concrete being 14 inches. Under the ordinary flow the concrete channel does not run full. During extreme high water the cross section of the channel is not sufficient to carry the entire flow so that once in a great while the water overflows the normal cross section.

Fig. 26 shows, in addition to the normal cross section of the channel, the sections where it enlarges to pass under a small culvert which carries a street over the brook. At section A-A the concrete is reinforced with half-inch rods spaced 10 inches apart. The culvert itself has a clear span of 8 feet and a total depth of 5 feet. The thickness of the invert of the culvert is 6 inches at the middle, gradually enlarging towards the abutments while the arch is 7 inches thick at the crown and increases gradually towards the abutments and is reinforced with $\frac{1}{4}$ -inch steel rods 8 inches apart on centers.

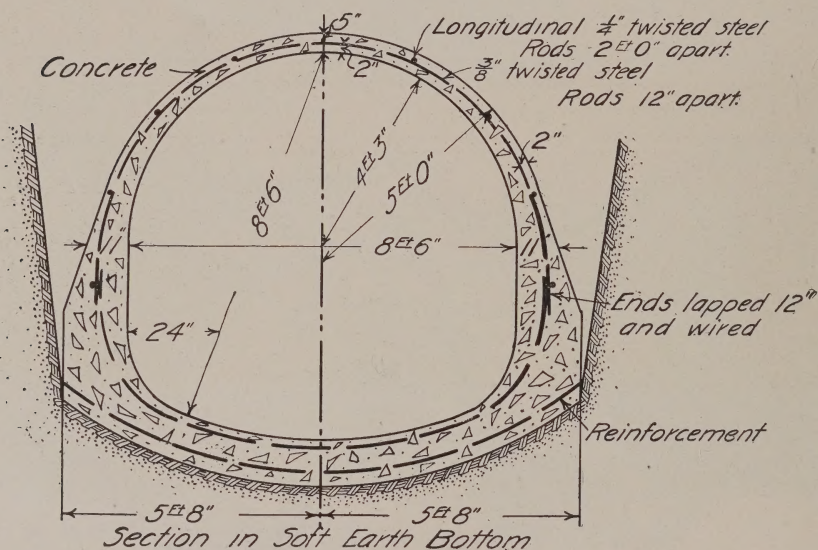


FIG. 27.—TYPICAL CROSS SECTION, JERSEY CITY CONDUIT

Fig. 25 is an illustration of the brook shown in detail in Fig. 26. The photograph was taken at a very low stage of the water.

For brook linings the concrete should be mixed 1 part "ATLAS" Portland Cement, $2\frac{1}{2}$ parts sand and 5 parts broken stone or screened gravel. Concrete linings should be laid in sections not over 20 feet in length, and the end of one section should be built into the adjacent section in a tongued and grooved manner.

Sometimes these concrete brook linings are connected with nearby sewers

so that the sewers are automatically or continuously flushed by some water passing from the brook into the sewer.

CONDUITS.

Oftentimes a covered conduit is necessary to carry the water of a brook located under a street surface. Such conduits may be made rectangular or circular in cross section. They are also frequently used for water supply lines where there is little or no pressure within the concrete conduit.

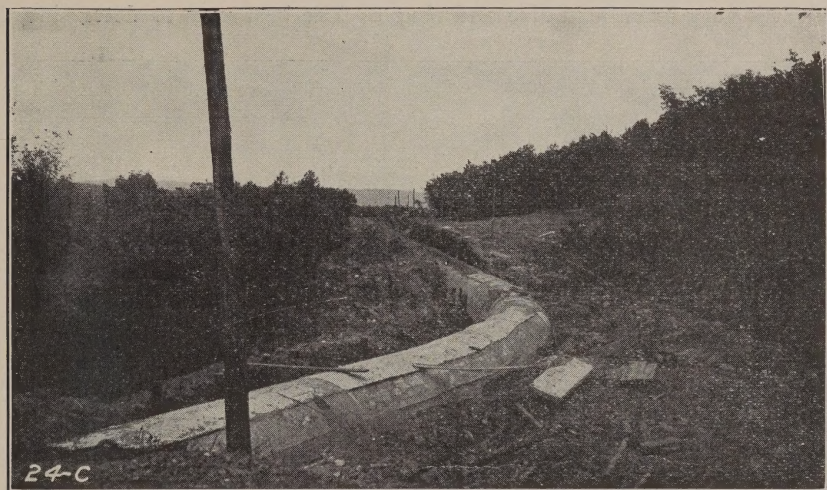


FIG. 28—JERSEY CITY CONDUIT.

Fig. 27 shows a typical cross section and Fig. 28 a photograph of a concrete conduit of the Jersey City Water Supply Company built to carry a water supply. This conduit is approximately 8 feet 6 inches inside diameter and for a length of about 20,000 feet is made of concrete. About 30,000 barrels of "ATLAS" Portland Cement were used in this conduit.

The thickness of the conduit at the crown varies from 5 to 8 inches depending on the kind of material in which the pipe is placed and the depth of the filling over the pipe. The section shown in Fig. 27 is typical of those used in soft earth.

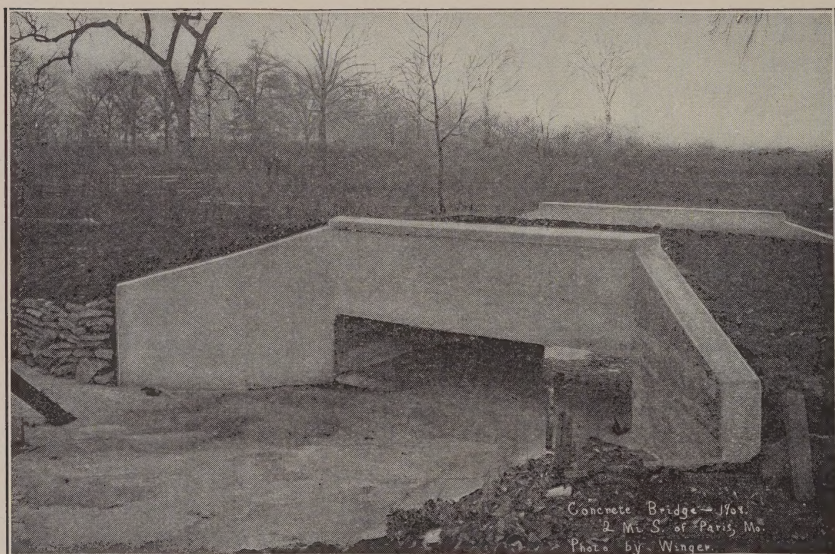
For sections laid in open trench the concrete was mixed 1 part "ATLAS" Portland Cement and 7 parts sand and ballast. The ballast was broken trap rock, the run of the crusher being used. All concrete was machine mixed and was very wet.

CHAPTER V.

CULVERTS.

Concrete is an excellent material for the construction of culverts as is shown by the great number of concrete culverts now being built for highways and railways. As the entire culvert is made of concrete there is nothing to decay and the excessive maintenance charges in timber construction are entirely lacking.

Culverts vary greatly in size and shape. The best way to determine the



BEAM BRIDGE NEAR PARIS, MO.

required size for an opening so that the waterway will be sufficient is to measure the width and depth of the stream at some narrow point near by during the high water stage, and if possible compare this size with that of culverts over the same stream in the neighborhood. With this information the width and depth of the culvert opening may be chosen.

Culverts may be either square, rectangular, circular, or arched in cross section. Generally the rectangular section is best because it conforms more nearly to the cross section of the water way and is cheaply and easily built. Where the appearance is of more importance than the cost, arch culverts are preferable to other styles. Whatever the form of cross section the construc-

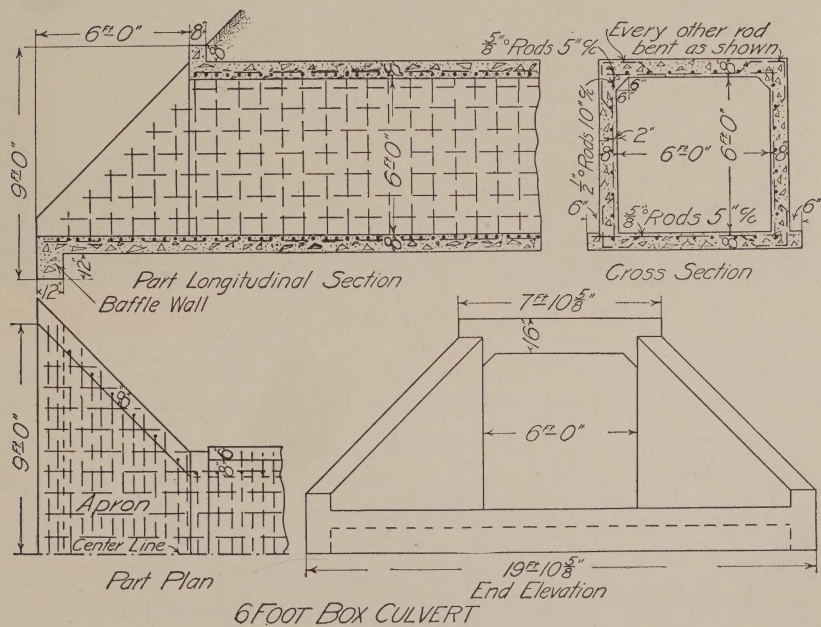
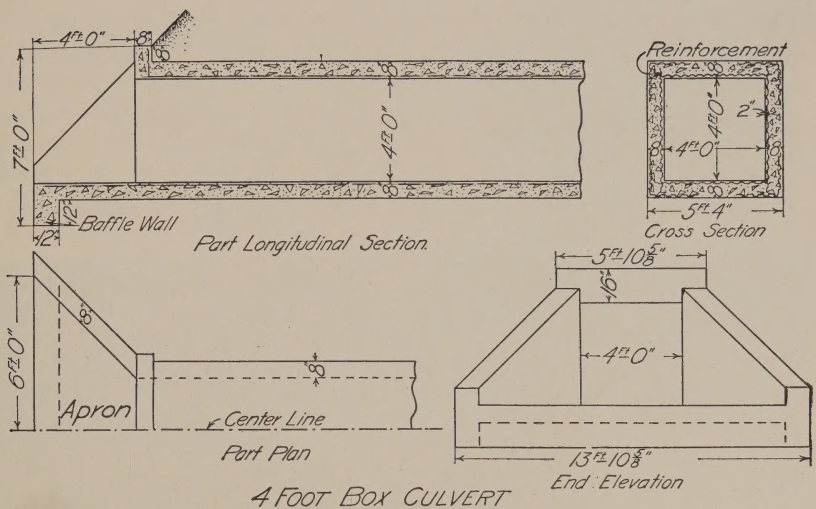


FIG. 29.—REINFORCED CONCRETE BOX CULVERTS.

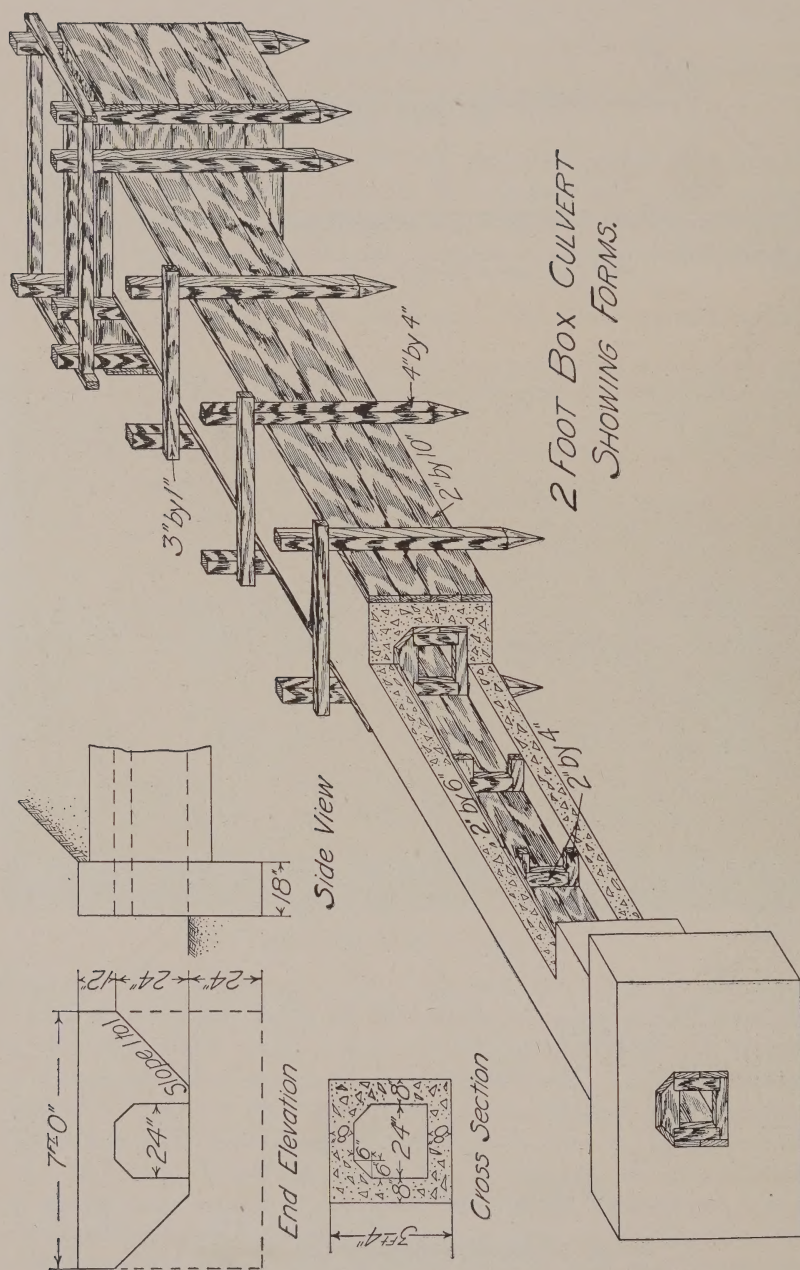
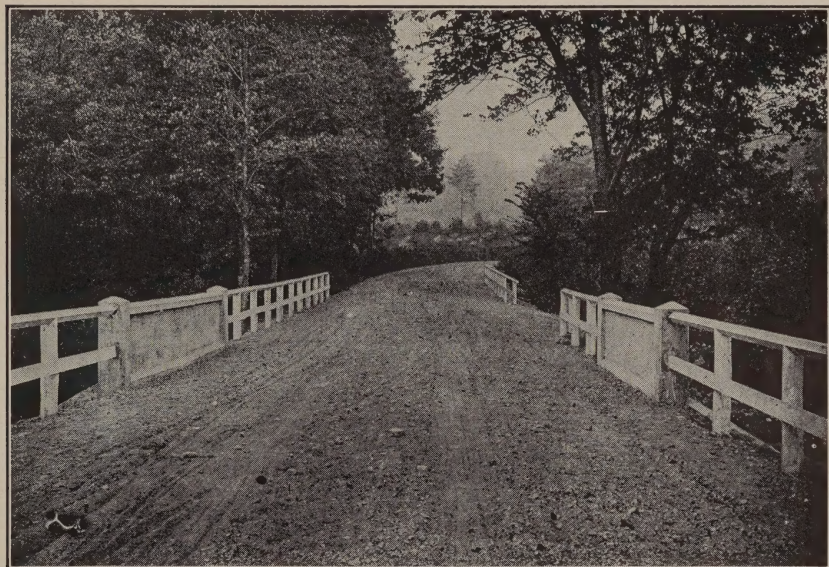


FIG. 30.—SMALL CONCRETE BOX CULVERT WITH FORMS.

tion should be such as to prevent undermining, that is, to prevent the water from running along the outside of the culvert and thus washing out the earth embankment.

Culverts with square or rectangular openings are called box culverts, and those with circular sections are called pipe or circular culverts. Pipe culverts are made entirely of concrete or else of tile or iron pipe with a concrete head wall at each end of the pipe where it projects from the sides of the road.



BEAM BRIDGE.

Concrete for culverts should be made one part "ATLAS" Portland Cement, two and a half parts sand, and five parts broken stone.

BOX CULVERTS.

Box culverts may have square or rectangular sections as in Fig. 29 or Fig. 32 or a section similar to that shown in Fig. 30. For small culverts, the last is a neat design, having an arch effect and yet being cheaply and easily constructed. The cost of the small box culvert shown in Fig. 30 may be slightly reduced if the cross section is made square, omitting the bevels at the upper corners.

Fig. 29 shows a good design for a 4-foot box culvert of ample strength to carry a highway.. To prevent undermining, a concrete invert or bottom is used and a baffle wall and apron at each end should be constructed as shown

although some culverts where the soil is hard do not need the apron, baffle wall or bottom. Cobble stones or paving bricks may be used instead of concrete for covering the bottom between the side walls. They may be laid even in running water and in case a dry season should occur the spaces between the stones or bricks may be filled with cement grout. Concrete must not be laid in running water for the cement will be washed out from the aggregate. This 4-foot box culvert has top, bottom and sides 8 inches in thickness and is reinforced with expanded metal No. 10 gage having 3-inch meshes, or with other similar reinforcement placed not less than $1\frac{1}{2}$ and not more than 2 inches from the inner surface of the culvert. The sheet reinforcement should also be placed in the apron and in the wing walls.

The lower part of Fig. 29 shows a design for a box culvert with opening 6 by 6 feet similar to the 4-foot box culvert above described except that round steel rods are used instead of sheet reinforcement. In the bottom of the culvert proper the rods running at right angles to the length of the culvert should be $\frac{5}{8}$ inch in diameter and spaced 5 inches apart. For the top they should be $\frac{5}{8}$ inch in diameter, spaced 5 inches apart and alternate rods should be bent, as shown in Fig. 29, to reinforce the side walls extending within three inches of the bottom surface of the concrete. This bending of the alternate rods in the top results in the vertical rods of the sides being spaced 10 inches apart. In the apron the $\frac{5}{8}$ -inch rods should be spaced 5 inches apart and should be bent up alternately so that the vertical rods in the wing walls are spaced 10 inches.

In addition to the rods above mentioned there should be a set of $\frac{1}{2}$ -inch diameter rods running parallel to the length of the culvert spaced 10 inches apart which should extend into the apron and wing walls at each end.

Fig. 31 and Fig. 32 show a reinforced box culvert built in Lenox, Massachusetts, in 1896, for the Massachusetts Highway Commission. The body of the culvert is reinforced with $\frac{7}{8}$ -inch square twisted steel rods 8 inches c. to c. at each corner where the side walls meet the top and bottom, those at the bottom corners being 24 inches long and bent, while those at the top corners are straight and 14 inches in length. Four counterforts for bracing the side walls are shown in the plan and also in section C1C, Fig. 32, are used in this culvert.

Forty cubic yards of broken stone, 16 cubic yards of sand, 55 barrels of cement, and 778 pounds of steel were used. One hundred twenty-one cubic yards of earth were excavated. The concrete mixture was about one part "ATLAS" Portland Cement, two and one-half parts sand, and five parts crushed stone, and the 44 cubic yards in the structure cost \$660, or \$15 per cubic yard. The earth excavation cost 75 cents per cubic yard. The total cost of the culvert to the Commission, exclusive of the macadam roadway was

\$809.67. The cement cost the contractor \$1.85 per barrel, plus 50 cents for hauling, making the price at the culvert \$2.35 per barrel. The contractor paid \$2 per load of about 1 cubic yard for the sand delivered at the culvert and about \$1.15 per cubic yard for the stone. About $3\frac{1}{2}$ or 4 days were required for excavating and the concreting extended over 24 days including delays. A small box culvert with an opening 2 by 2 feet is shown in Fig. 30 in which the head wall, culvert proper, and arrangement of forms are all clearly illustrated. If the soil is compact material like hard clay, where the excavation can be made to the exact size and shape of the culvert, the outer forms may be omitted, the concrete being deposited directly on the bottom of the

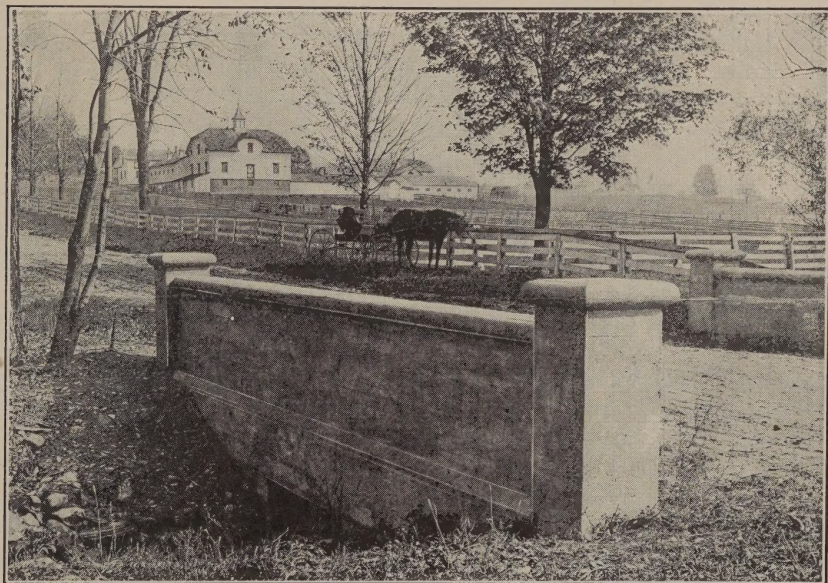


FIG. 31.—REINFORCED CONCRETE BOX CULVERT AT LENOX, MASSACHUSETTS.

trench to form the invert of the culvert, then the inner form set in place and the concrete deposited between it and the walls of the trench.

The inner forms consist of frames made of three pieces of 2 by 4 inch and one piece of 2 by 6-inch joists, notched as shown. Around these frames boards are set. The upper 2 by 6 piece is not nailed so that in removing the inner forms after the concrete has hardened this upper piece is first knocked out and then the 2 by 4-inch pieces and finally the boards.

Another type of small culvert and form as used by the Iowa State Highway Commission is shown in Fig. 33.

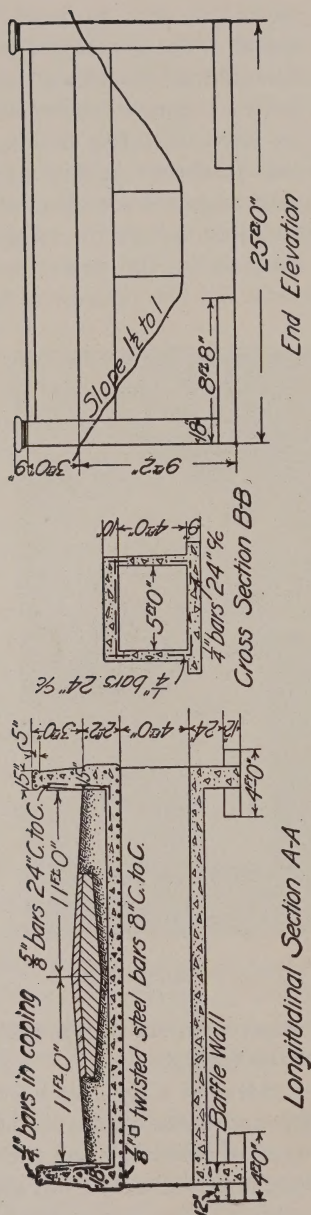


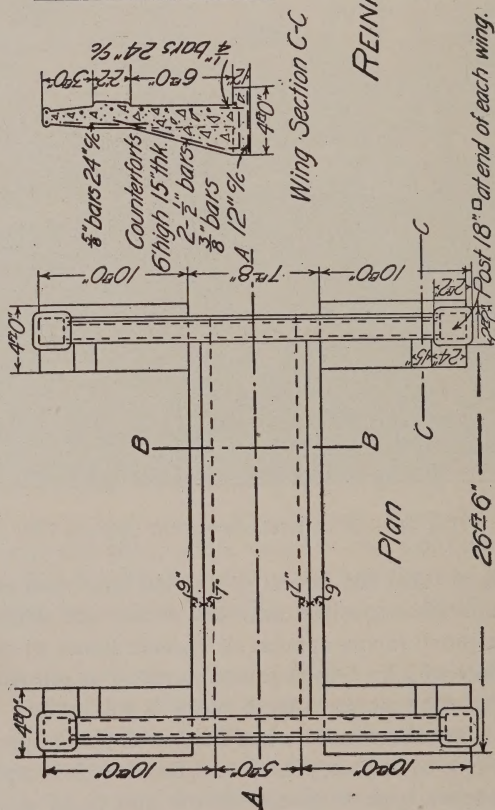
FIG. 32.—REINFORCED CONCRETE BOX CULVERT AT LENOX, MASSACHUSETTS.

Size	No	Lg	Location
1/8"	38	5'4 10"	In cover-body section
1/2"	8	10'4 10"	In counterforts
	8	2'4 16"	Horizontal for End Walls
	12	9'4 6"	" " "
3/8"	36	3'4 6"	In Wing Boxes
	8	2'4 10 0"	" " Copings
	24	1'4 2 0"	Ties-cover and side walls
1"	24	2'4 0 0"	Base and side wall ties
	20	1'4 4 6"	" " " Wing " "
3/8"	22	5'4 0 0"	Verticals-Wing walls

Concrete 44 Cu. Yds.

Excavation about 125 Cu.Yds.

REINFORCED CONCRETE CULVERT
LENOX, MASS.



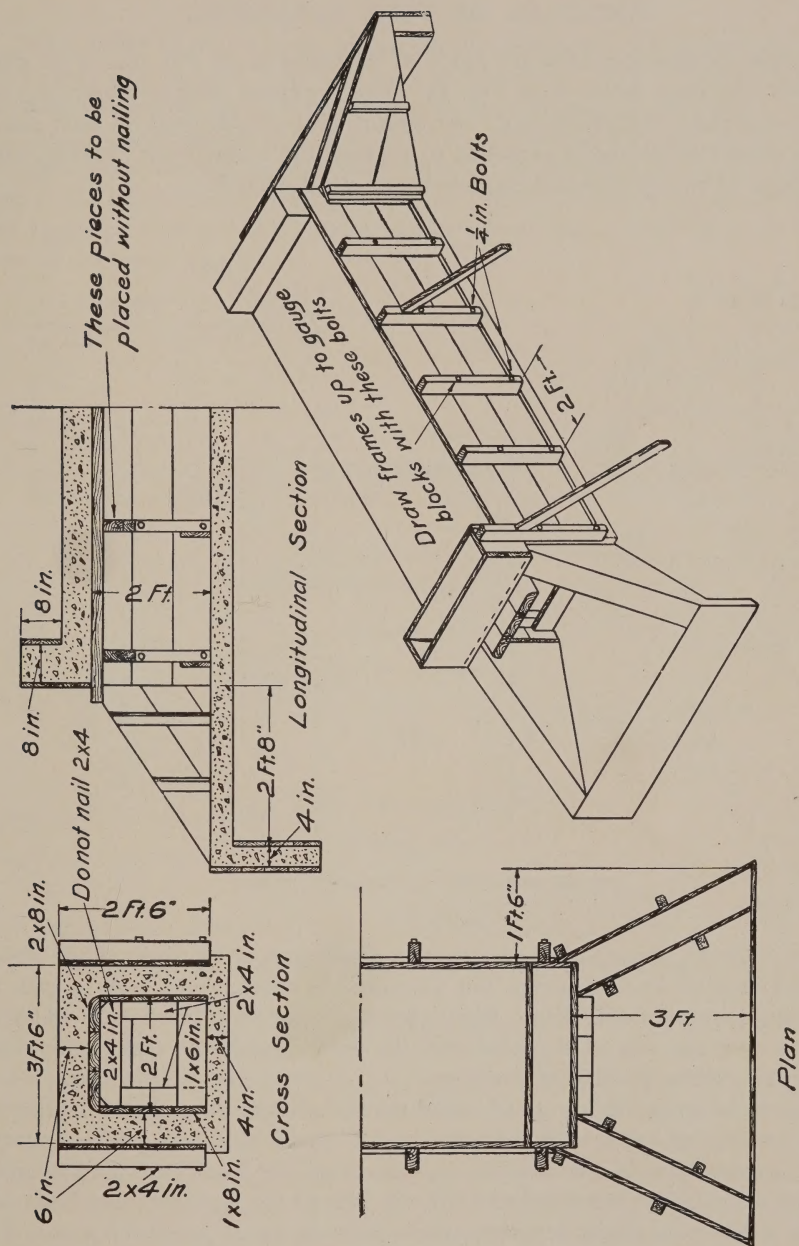


FIG. 33.—SMALL BOX CULVERT AND FORMS, IOWA STATE HIGHWAY COMMISSION.

CIRCULAR OR PIPE CULVERTS.

Circular or pipe culverts are made of concrete as in Fig. 34, or of metal with concrete head walls as in Fig. 35. The concrete culvert shown is 3 feet in diameter and is not reinforced. An apron with a baffle wall on each side as well as on the outer end is provided to prevent the water from running along the outside of the culvert and thus washing out the earth.

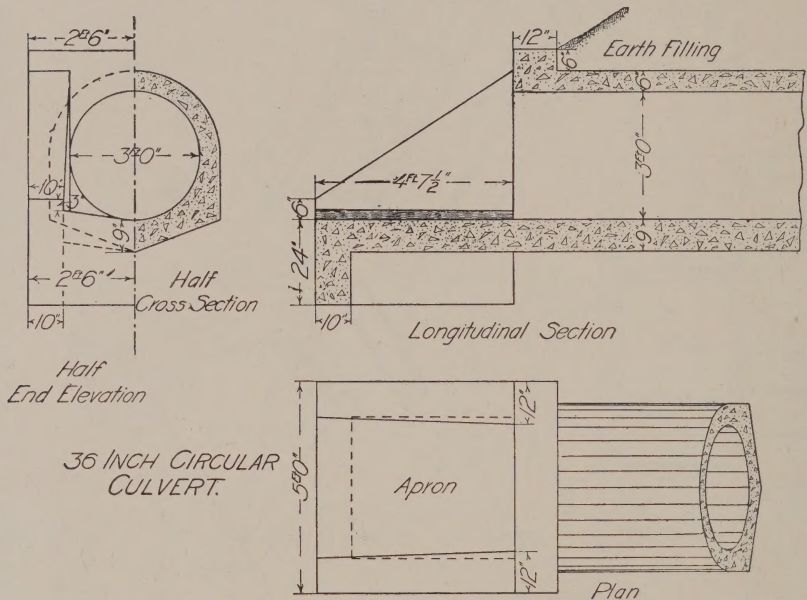


FIG. 34.—CONCRETE CIRCULAR CULVERT.

Pipe culverts are made of cast iron or sheet iron or of tiles. They should have fall enough so that water will not stand in them, a slope of $\frac{1}{4}$ inch per foot being generally sufficient. They should also have at least 12 to 18 inches of earth over the top of the pipe and the earth should be thoroughly compacted around the outside of the pipe.

To prevent undermining, head walls should always be used with pipe culverts. In Fig. 35 head walls for four sizes of metal pipes are shown and they are all similar except that for the 24-inch pipe the head wall has a coping 6 inches deep projecting 2 inches from the face of the wall, and the head wall for the 3-foot pipe has a concrete apron 6 by 24 by 48 inches in size. This apron should slope up at the inlet and down at the outlet.

The number of cubic yards of concrete in one head wall for the 12, 18, 24, and 36-inch pipe is 0.64, 1.04, 1.47, 2.57 respectively. The 2.57 cubic yards in the headwall for the 36-inch pipe includes the concrete in one apron.

If the proportions are one part "ATLAS" Portland Cement, two and one-half parts sand and five parts broken stone or screened gravel, 1 $\frac{1}{3}$ bbls. cement (each barrel being the same as four bags) will be required for a cubic yard together with about $\frac{1}{2}$ cubic yard of sand and a cubic yard of broken stone or screened gravel.

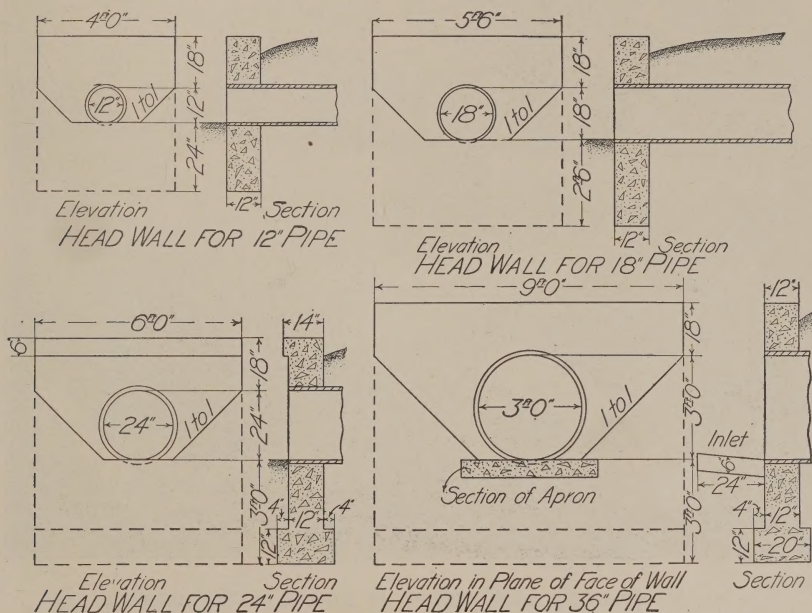


FIG. 35.—CONCRETE HEAD WALLS FOR METAL CULVERTS.

ARCH CULVERTS.

As previously stated, arch culverts are more expensive and more difficult to build than box culverts, but nevertheless they are frequently used where an artistic design is desirable. The culvert of 5-foot span, illustrated in Fig. 36, is very similar to the design for the 5-foot span shown in Fig. 39, and was built in Bureau County, Illinois, by the Illinois Gravel Company of Princeton, Illinois. It contains 11.4 cubic yards of concrete mixed one part "ATLAS" Portland Cement to six parts sand and gravel, using gravel as the large aggregate with coarse sand to fill the voids. The cost of the cement delivered

at the bridge was \$1.35 per barrel. Actual cost of the culvert was \$75.00, which included long haul charges for gravel.

Figs. 37, 38 and 39 show designs for arch culverts of 5, 8, and 10-foot clear spans respectively, suitable for highway construction where the soil is firm, as compact sand or hard clay. If the soil is soft clay or loam, the footings should be made wider so as to give a larger bearing area for the walls as well

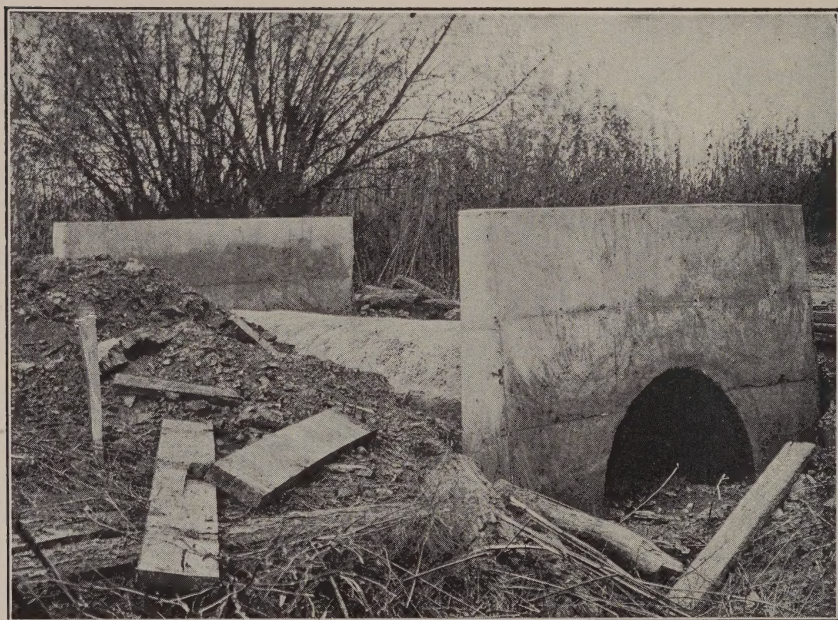


FIG. 36.—CONCRETE ARCH CULVERT IN BUREAU COUNTY, ILLINOIS.

as for the arch proper. Of course, if the soil is too soft, box instead of arch culverts should preferably be used, or else the bearing power of the soil should be increased as indicated below under "Preparing the Bed."

As shown in Fig. 38, each end wall of the 10-foot span should be reinforced with 14 long vertical rods and with 8 short bent rods, the latter extending horizontally two feet into the arch and vertically two feet into the end walls; and in addition there should be 4 long horizontal rods in each end wall. All rods are $\frac{1}{2}$ inch in diameter. The 5-foot span has no reinforcement except 5 bent rods to tie each end wall to the arch.

The designs show a width of 10 feet between the walls, but this can be increased to any distance desired.

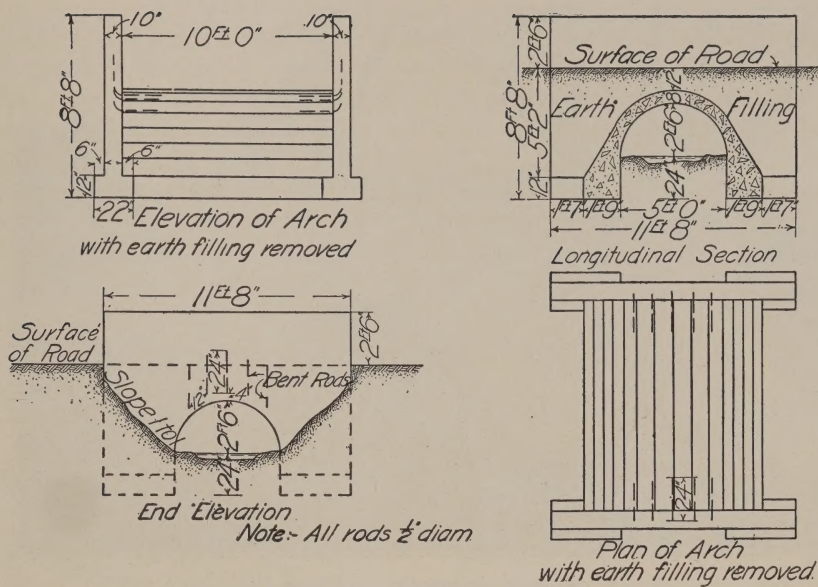


FIG. 37.—ARCH CULVERT FOR FIVE-FOOT SPAN.

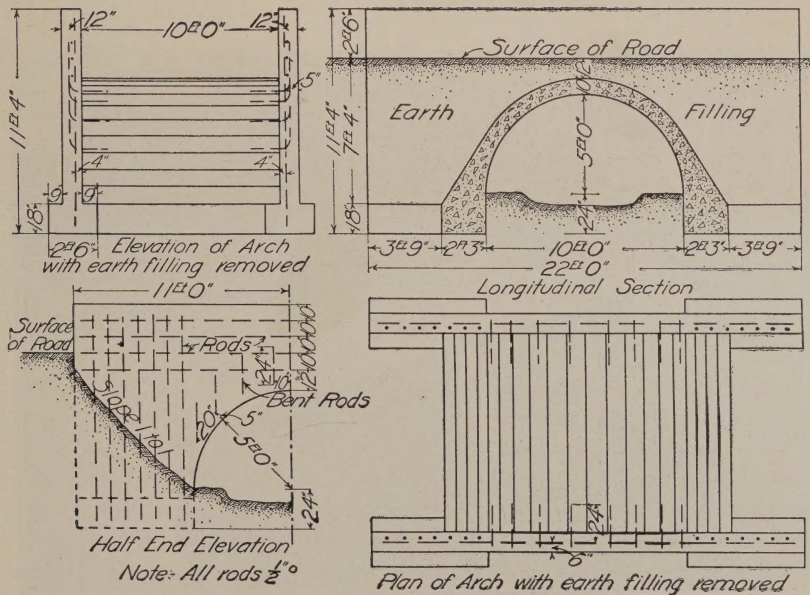
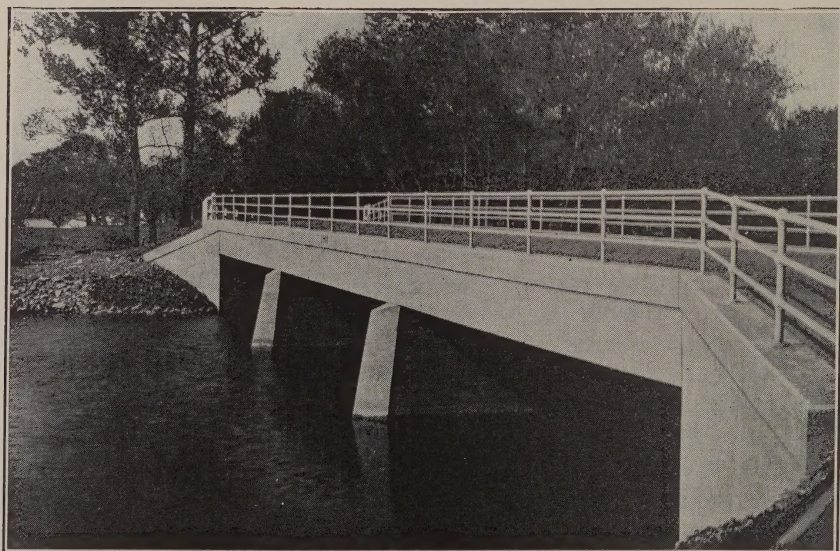


FIG. 38.—ARCH CULVERT FOR TEN-FOOT SPAN.



ARCH IN BUREAU CO., ILLINOIS



BEAM BRIDGE, GROTON, MASS.

In the 5-foot span there are 4.25 cubic yards in each end wall and 4.73 cubic yards in the arch between the end walls, making a total of 13.23 cubic yards of concrete in the structure. In case the roadway is wider than here assumed, the total number of cubic yards of concrete in the structure may be computed by adding to 8.5 the product of 0.473 times the distance in feet between the end walls; 8.5 being the cubic yards of concrete in the two walls and 0.473 the number of cubic yards of concrete in one foot length of arch.

The quantities of materials for arch culverts, 5, 8 and 10-foot span, are given in the following table.

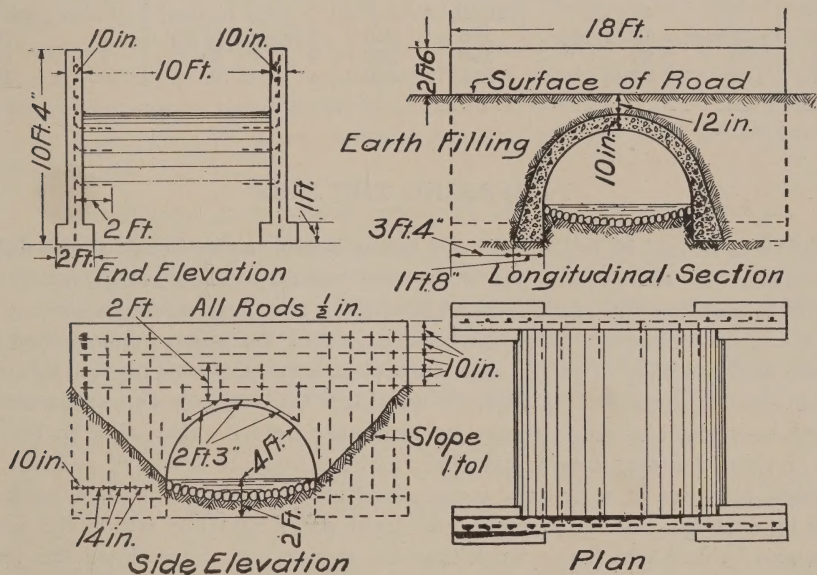


FIG. 39.—ARCH CULVERT FOR EIGHT-FOOT SPAN.

QUANTITY OF MATERIAL FOR ARCH CULVERTS

Proportions: 1 Part "ATLAS" Portland Cement to 2 1-2 Parts Sand to 5 Parts Gravel or Stone

Materials for Culvert for 10-ft. Roadway (See Figs. 37, 38 and 39)				Extra Material for Each Additional Foot Width of Road		
Span of Culvert	Cement	Sand	Screened Gravel or Stone	Cement	Sand	Screened Gravel or Stone
feet		cu. ft.	cu. ft.		cu. ft.	cu. ft.
5	50 bags or 12 ½ bbls.	120	240	2 bags or ½ bbl.	5	10
8	80 " " 20 "	190	380	3 " " ¾ "	7 ½	15
10	115 " " 28 ¾ "	275	550	4 " " 1 "	10	20

PREPARING THE BED.

Culverts should be built when the water is low in the brook at the site of the culvert. In many cases the water will cause no trouble if in excavating for the foundation the earth is thrown up into two parallel dams so that the brook can flow between them, the foundation for the culvert being then laid outside of these piles of earth. Sometimes the stream can be carried in a new trench around the side. If there is considerable water in the brook and it cannot be carried around, it may be necessary before excavating to drive a row of closely fitting boards parallel to the stream in front of each of the proposed trenches in which the foundations are to be laid and then bank the earth against the boards to make two tight dams between which the brook flows and behind which the work may be carried on. Sometimes the water may be carried in a box trough as shown in Fig. 41.

In some cases a hand pump may be needed to keep down the water in trenches. Trenches for foundations of whatever kind should in all cases be excavated to a depth below frost, but if the brook is never dry two or three feet below the bed of the stream will be sufficient.

The preparation of the bottom of the trenches to receive the concrete footings of the culvert as a rule should not be difficult, for the concrete can be laid directly on the soil when it is hard clay, compact sand or gravel. If the soil is soft sand or soft clay or loam it should be compacted by ramming, but if too soft to be rammed the bearing power of the soil can be increased by adding a layer of clean sand, cinders, or broken stone before ramming. In extreme cases, where the soil is very soft, it may be necessary to increase the width of the base of the culvert walls or to build these walls on a layer of 4-inch planks to distribute the weight over a considerable area of the soil.

Occasionally, piles may be necessary. Where the soil is as soft as here indicated a box culvert is preferable to an arch.

Planking should never be used under a foundation unless it will at all times be covered with water.

FORMS FOR ARCH CULVERTS.

The forms are set after the soil has been prepared to receive the concrete. Outer wing wall forms are generally constructed of 1-inch boards laid horizontally and braced with 2 by 4-inch or 2 by 6-inch studs. The forms on the inner side of the wing walls are laid horizontally and cut to fit approximately the shape of the arch. The outer surface of the arch proper needs forms from the bottom up to about $\frac{1}{2}$ to $\frac{3}{4}$ of the way to the top and should be made of 1 by 4-inch or 1 by 6-inch boards, attached at their ends to the inside wing wall forms.

Centering for circular arch culverts is shown in Figs. 40 and 41. The sills should be set first and braced; then the circular forms, spaced 2 feet apart for 1-inch lagging, 3 to 4 feet apart for 2-inch stuff, should be set upon the wedges resting on the upper sills. The lagging shown in the drawings, which should be of narrow width to fit the circle, is then fastened to the circular centers. The outer forms must be braced by tying across the top of the culvert or by using braces against the earth on either side.

In Fig. 41 the inside wall forms have a 3 by 4-inch or a 4 by 4-inch ranger set across the top of the cleats on which the wedges are placed to support the arch forms. The wedges should separate the two forms at least 3 inches in order to facilitate the removing of the arch forms. A strip of sheet iron may be nailed to the side forms, as shown, and lap over on to the arch form to prevent the concrete from getting in between the forms. After removing the arch forms the side forms can be readily removed.

The forms should be oiled before placing the concrete.

The concrete for culverts should be of a mushy consistency and should be deposited and lightly tamped in layers 6 or 8 inches thick. If possible the concrete of the whole arch and wing walls should be deposited at one time, but where the work is so large as to make it impossible to do this, the arch should be divided into circular sections, and one section laid at a time. Twenty-eight days should be allowed for the concrete to set, after which time the wedges are knocked out and the centers removed. The earth filling can be placed as soon as the connecting is completed.

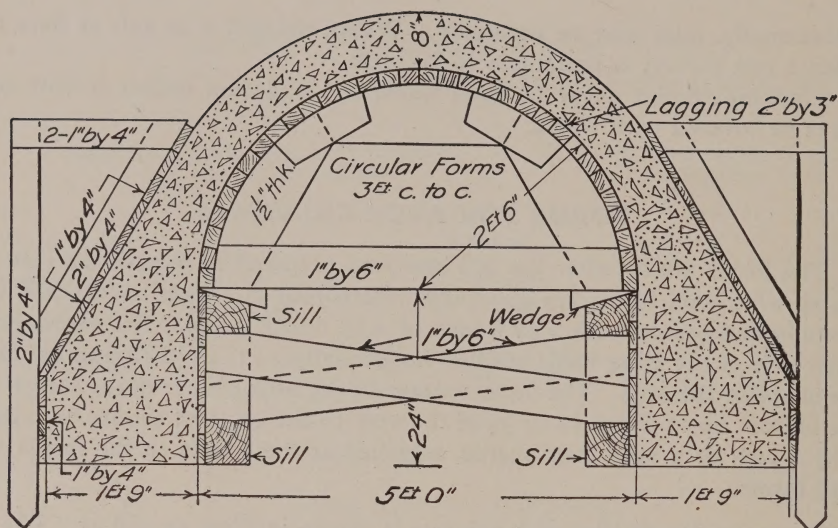


FIG. 40.—FORMS FOR FIVE-FOOT CIRCULAR ARCH.

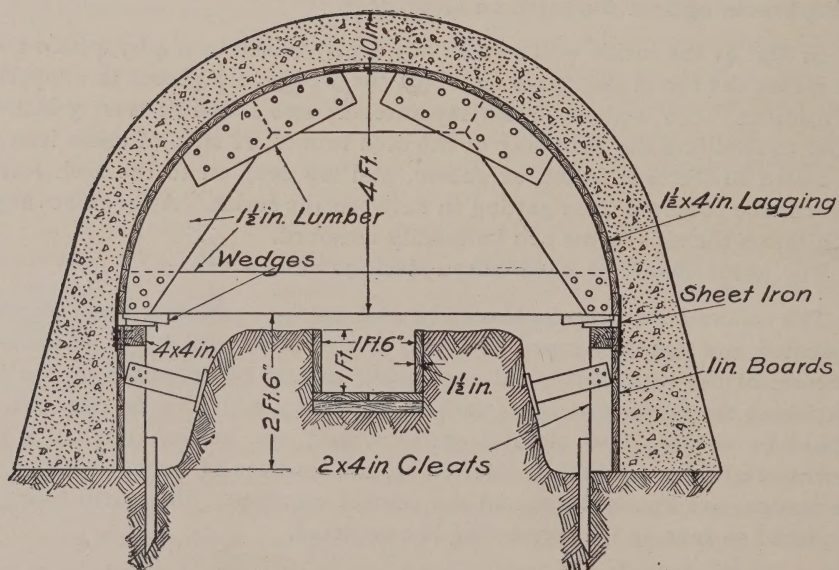


FIG. 41.—FORMS FOR EIGHT-FOOT CIRCULAR ARCH.

CHAPTER VI.

BEAM BRIDGES

Owing to the demand for more permanent bridges, concrete is fast replacing wood and steel for structures of all types, especially for spans under 100 feet. Not only is concrete an excellent material for these short spans, but where the foundations are good, concrete arches are well suited even for structures 200 feet in length or even longer. The average life of a wooden bridge is only about 9 years, and of a steel bridge not over 30 to 40 years, and

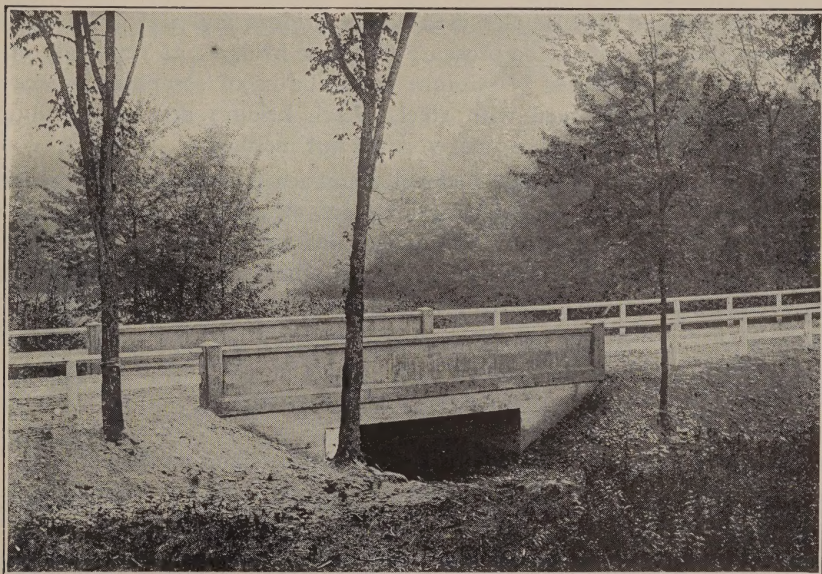


FIG. 42.—CONCRETE BEAM BRIDGE.

even during this time there is a continual outlay for repairs and painting. A concrete bridge will last indefinitely and with practically no maintenance.

In the State of Illinois alone \$1,888,724 was expended for highway bridges in the year 1905, a considerable part of this being devoted to repairing and replacing wooden or metal structures. It is evident that more attention should be given to the design and construction of highway bridges.

In addition to their natural permanence, concrete bridges are cheap in first cost and are absolutely proof against tornadoes, high water, and fire. *Further-*

more, by employing local labor the money spent in their construction remains almost entirely in the community in which the bridge is built, there is less difficulty in securing the necessary skilled labor during times when the building trades are active and there is no waiting for structural steel since rods can be had at short notice.

The greatest care should be taken in the design and construction of concrete bridges. Designs must be made by an engineer familiar with concrete construction except for small arched structures where the designs given in this book may be used by one who thoroughly understands the use of concrete.

KINDS OF CONCRETE BRIDGES.

Concrete bridges may be classified as flat bridges and arch bridges. Flat bridges are those in which the pressure from the bridge acts vertically on the supports and consist either of straight flat slabs or of combined beams and slabs of concrete reinforced with steel. Arch bridges are curved and the pressures upon the supports are not vertical but inclined.

Flat construction is suitable in level countries for short spans, generally not exceeding 30 or 40 feet, and for locations where the foundation is soft material. Arches are especially economical in localities where the roads can be built considerably above the streams and where there is rock, firm sand or gravel or other similar hard soils which afford good foundations.

TYPES OF FLAT BRIDGES.

Flat bridges may be divided into three types, slab, combined beam and slab, and girder bridges. The first two types are used for short spans and the girder type is preferably used for spans from 25 to 40 feet.

A slab bridge, Fig. 43, consists essentially of a flat slab of concrete of uniform thickness reinforced with steel and resting on the supporting walls. In some cases, as shown in Fig. 44, the slab is supported by two longitudinal girders. The macadam roadway is laid directly on the slab—or by employing method and materials described in Chapter III the slab may form a concrete pavement.

Combined beam and slab bridges, Fig. 45, consist of a series of reinforced concrete beams, laid parallel to the roadway, and a flat slab of concrete upon which the roadway is laid. These beams rest on, and are usually thoroughly united with, the abutment walls. The beams and slab must be laid at one time so as to form a homogeneous structure.

Girder bridges, Fig. 48, are usually composed of two large reinforced concrete beams, called girders, one on either side of the roadway supporting intermediate cross beams which in turn carry the slab upon which the roadway is laid. A weight on the roadway, as from a wagon wheel for example, is therefore transmitted from the roadway to the slab, then to the beams, then to the girders and finally from the girders to the supports.

PROPORTIONS FOR CONCRETE.

For bridges such as described in this chapter, the concrete should be mixed one part "ATLAS" Portland Cement, two parts sand, and four parts broken stone or gravel for slabs, beams, girders, and other parts of the deck. For abutment walls and foundations use one part "ATLAS" Portland Cement, two and one-half parts sand, and five parts broken stone or gravel.

The materials must be thoroughly mixed and must not be separated in handling.

Care must be taken to work the concrete in between and around the steel rods without displacing them.

The forms must be strong and under the bridge they must be left in place 28 or 30 days or even longer in the fall and spring.

STEEL REINFORCEMENT.

The reinforcement shown in the designs of this chapter is medium steel, either with round or deformed surfaces, the latter giving better bond with the concrete.

SLAB BRIDGES.

A slab bridge similar to that shown in Fig. 43, representing a design practically the same as the standard design of the Pennsylvania State Highway Department, is of simple construction and permanent character. This bridge, which has a clear span of 16 feet, consists of a reinforced slab 15 inches thick connected rigidly to two abutment walls of the same thickness. The side walls serve only as protecting parapets. The principal reinforcement in the slab consists of steel rods $\frac{3}{4}$ inch square, spaced 5 inches apart on centers, running lengthwise of the roadway and bent at the abutments. The design shown differs from the standard of the Pennsylvania State Highway Department in that alternate bars are bent upward at the junction of the slab and abutment walls so as to lie near the outer surfaces of the slab and wall. Rods placed in these positions at the upper corners prevent cracks from forming in the concrete at the top of the slab near the abutment wall. In addition $\frac{1}{2}$ -inch square

rods are used in the slab, abutments, and side walls as shown in the cut. The distance from the bottom of slab to top of upper footing course is shown as 6 feet, but this may be increased to 10 feet if necessary to give the proper waterway. For greater heights than 10 feet, the thickness and reinforcement of the walls and footings should be increased. The total length of each side wall also must be increased 3 feet for every 1 foot increase in the height over that shown in the cut.

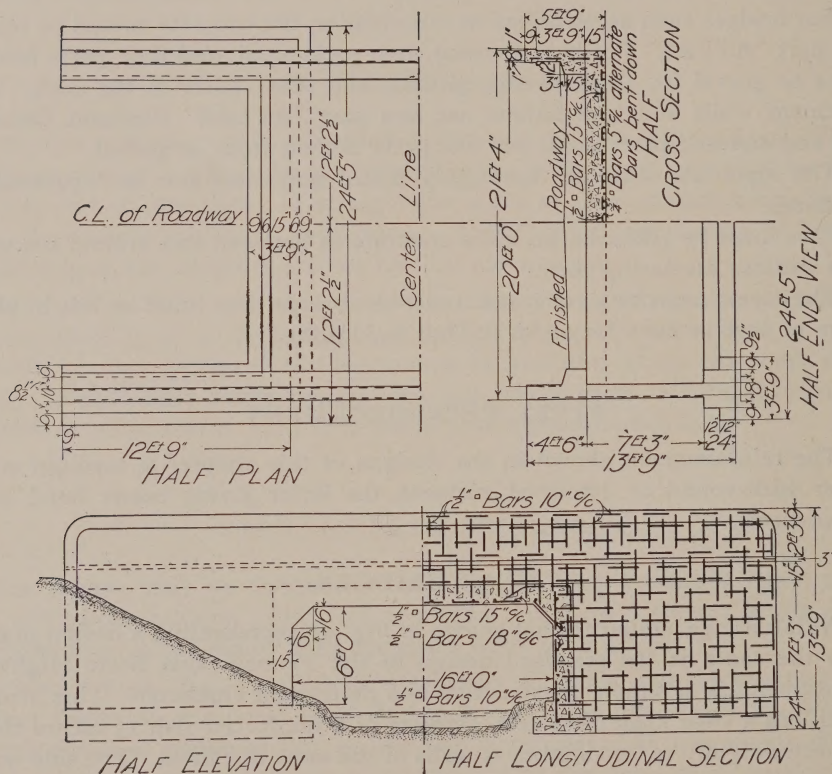


FIG. 43.—SLAB BRIDGE WITH SPAN OF 16 FEET.

The designs for spans other than 16-foot, differ in the thickness of the concrete and in the amount of reinforcement. Each span is a special design in itself and it is just as necessary to have exactly the correct amount of concrete and steel rods for each individual design as it is to use the right size of I-beams or trusses in a steel bridge.

The clear width of the roadway in the design illustrated is 20 feet, but this may be changed to suit local conditions, using for a 16-foot span the same thickness of slab and the same size and spacing of reinforcement. There are 73 cubic yards of concrete and 4,375 pounds of steel rods in this bridge. For every 1-foot increase or decrease in width of roadway, there will be an increase or decrease in the volume of concrete of 1.91 cubic yards, and in the weight of steel rods of 125.7 pounds. With the aid of these figures, the total quantities may be computed for a bridge having a roadway whose width differs from that shown in the drawing.

The accompanying table shows the proper dimensions and quantities of materials for slab bridges similar to that illustrated in Fig. 43. The quantities of materials given in the table are for the entire bridge, including abutments, sidewalls and slab.

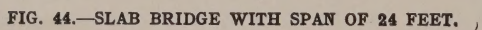
PRINCIPAL DIMENSIONS AND QUANTITIES OF MATERIALS FOR SLAB BRIDGES
SIMILAR TO BRIDGE IN FIG. 43

Clear Span in Ft.	Thick-ness of Slab in Inches	Longitudinal Bars		Abutment Walls		Length of Side Walls, Feet		Cu. Yds. of Concrete		Pounds of Steel Rods	
		Size of Square Bars, Inches	Distance c. to c., Inches	Thick-ness, Inches	Width of Footing, Inches	6 Ft.*	8 Ft.*	6 Ft.*	8 Ft.*	6 Ft.*	8 Ft.*
8	9	$\frac{5}{8}$	6	8	20	32.0	38.0	43	53	2715	3440
10	11	$\frac{5}{8}$	5	11	23	34.5	40.5	49	60	3195	3880
12	13	$\frac{5}{8}$	5	13	27	37.0	43.0	57	69	3420	4100
16	15	$\frac{3}{4}$	5	15	45	41.5	47.5	73	87	4375	5035

*Distance in feet from top of footing course to bottom of slab.

A slightly different style of design for a slab bridge from that just described is shown in Fig. 44, which represents a standard design of the Illinois State Highway Commission for a 24-foot span carrying a roadway 16 feet wide. Here the slab is supported by the side girders which at the same time serve as side railings or parapets. The wing walls are set at an angle with the abutments and are reinforced with $\frac{1}{2}$ -inch rods laid horizontally near the front face and vertically near the back face. The main abutment walls are 14 inches thick and have a maximum height of 14 feet 4 inches from the bottom of the foundation. These walls as well as their foundations are reinforced with $\frac{1}{2}$ -inch bars as indicated in the figure.

The floor slab is 11 inches thick and is reinforced with $\frac{3}{4}$ -inch bars, 4 inches apart on centers running across the roadway and bent up into the gir-



ders, also with $\frac{1}{2}$ -inch bars spaced 12 inches apart on centers running lengthwise of the bridge. The reinforcement of the girders consists of nine horizontal bars imbedded in the lower part and several U-shaped bars placed vertically at short intervals throughout the length of the beam.

Care must be taken to set the steel rods in the places called for by the plans; thus, in the footings of the abutment walls the horizontal rods must be near the bottom, not the top of each footing. Rods are placed in concrete to perform certain definite purposes and too much care cannot be taken to see that they are set right and that they do not get moved out of place during the progress of the work.

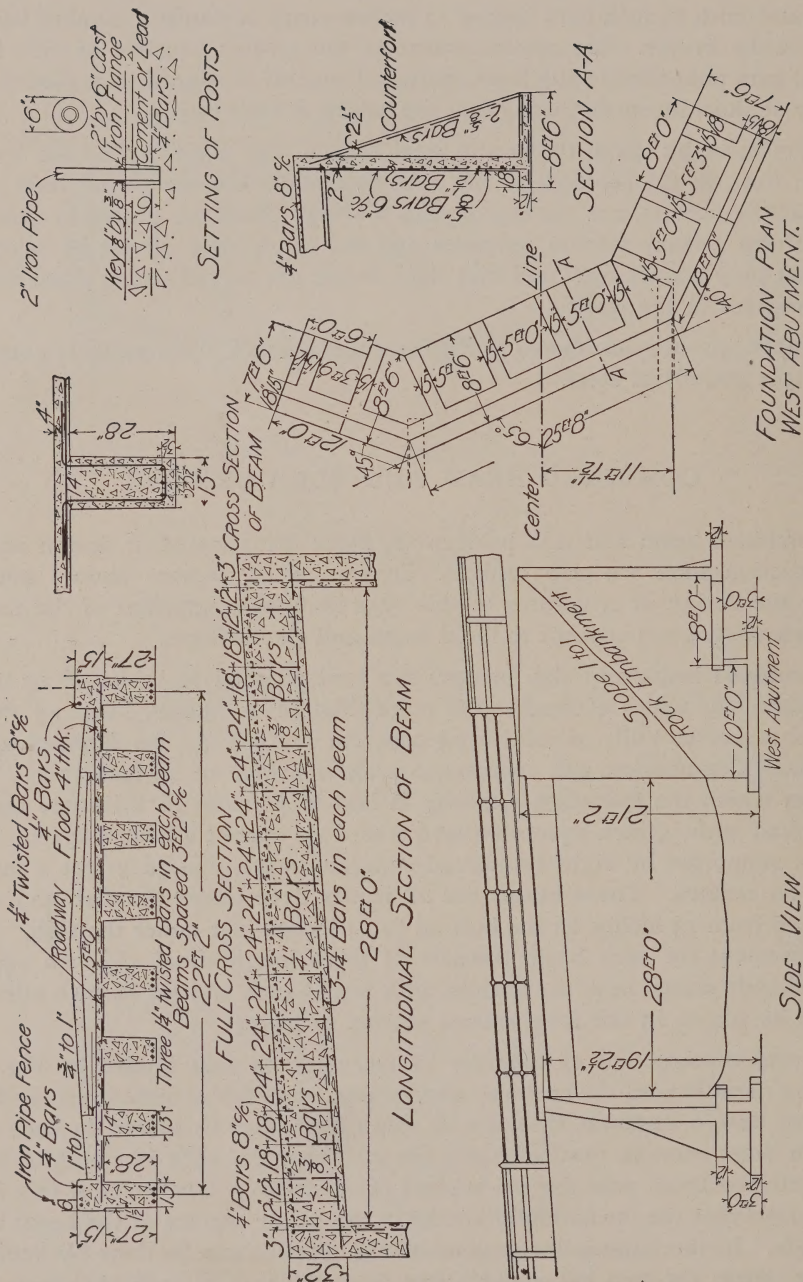
In this 24-foot span, shown in Fig. 44, there are 82.7 cubic yards of concrete and 7,584 pounds of steel.

COMBINED BEAM AND SLAB BRIDGES.

Combined beam and slab bridges are more complicated in design and in construction than are slab bridges. Inexperienced persons should not attempt the design of structures of this type and those ignorant of the use of concrete should not attempt to build beam and slab bridges.

Combined beam and slab bridges are well adapted to spans of 15 to 30 feet where the width of roadway is more than 16 or 18 feet. Fig. 45 shows such a structure built of reinforced concrete in 1906 by the Massachusetts Highway Commission and represents a skew bridge of 28-foot span. The slab on which the macadam roadway is laid is 4 inches in thickness and is reinforced with $\frac{1}{4}$ -inch square twisted steel rods spaced 8 inches apart. The slab is supported by eight reinforced concrete beams spaced 3 feet 2 inches apart on centers. These beams are 28 inches deep under the slab and vary in width from 13 inches on the bottom to 14 inches just under the slab. The reinforcement for each beam consists of three longitudinal $1\frac{1}{4}$ -inch square twisted rods placed near the bottom with ten $\frac{3}{8}$ -inch and six $\frac{1}{4}$ -inch stirrups placed as shown in the longitudinal section of beam.

In the construction of concrete beams, such as that shown in Fig. 45, running parallel with the roadway and resting upon the abutment cross walls, the best design demands that one or more bent bars be placed in each end of each beam running vertically into the wall near the back face and horizontally into the beam near the top surface of the beam. Bent rods of this kind tend to prevent the formation of cracks in the upper surface of the beam near the ends. In the longitudinal beams in Fig. 45, this can be done by bending up the center $1\frac{1}{4}$ -inch bar about 3 feet from the face of each abutment and



continuing this bar near the upper horizontal surface of the beam thence around the corner down into the abutment walls about 4 feet.

The abutments, Fig. 45, which are irregular in shape on account of the skew on which the bridge crosses the stream, are braced with counterforts 15 inches thick spaced about 5 feet apart. Each counterfort has two $\frac{5}{8}$ -inch tie bars imbedded $2\frac{1}{2}$ inches in from the back surface and bent down into the footing so as to form a secure tie. The footing is also reinforced with $\frac{3}{8}$ -inch bars running perpendicular to the face of the abutment and spaced 12 inches apart on centers. The abutment and wing walls are 15 inches thick and have $\frac{1}{2}$ -inch horizontal bars spaced from 12 to 24 inches apart on centers and $\frac{5}{8}$ -inch vertical bars 6 inches apart on centers.

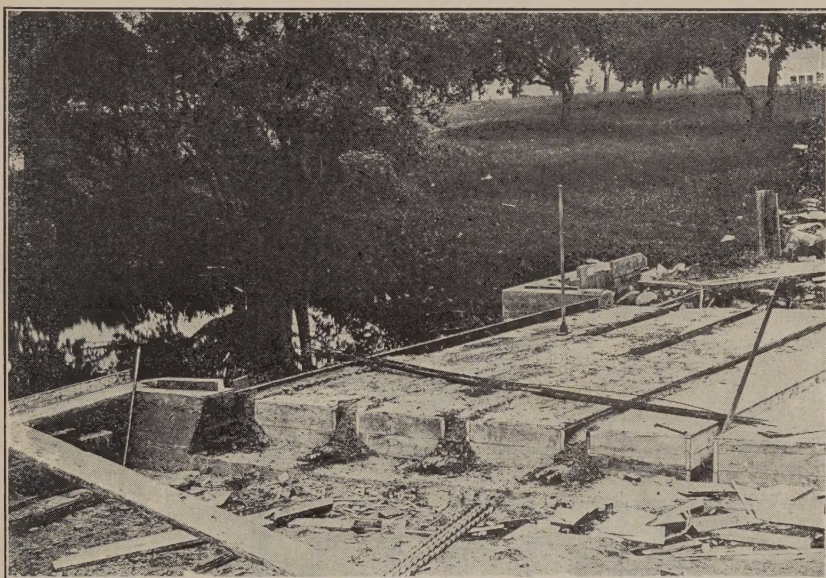
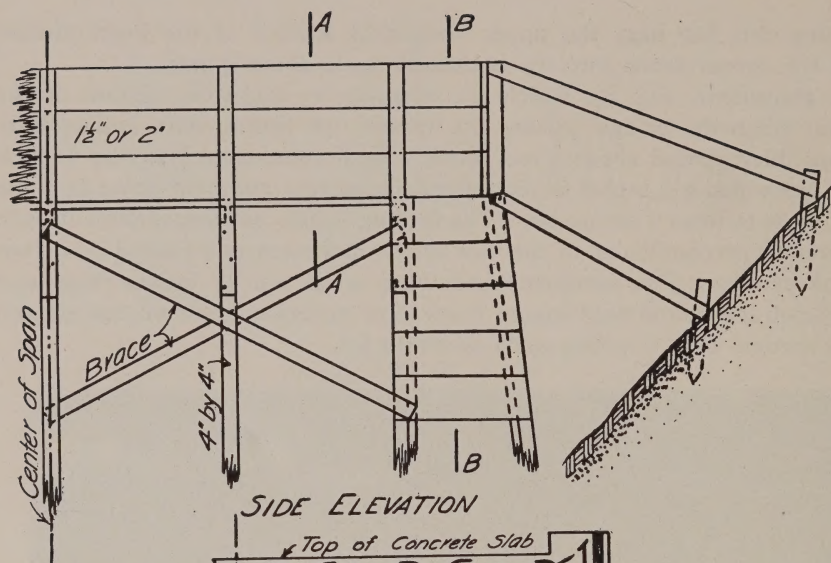


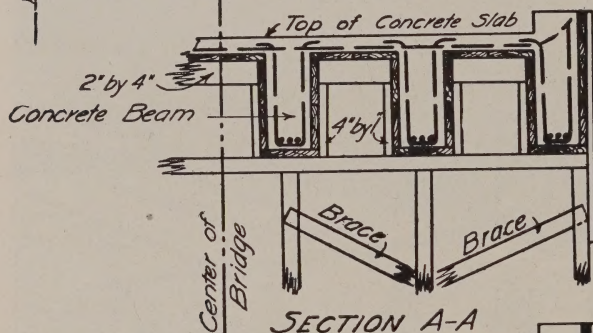
FIG. 46.—FORMS FOR SLAB AND BEAM BRIDGE.

One hundred and seventy-seven cubic yards of 1:2:5 "ATLAS" Portland Cement concrete were used in the construction of this bridge. The total cost of the bridge was \$2,286.50, the cement costing \$2.30 at the nearest railroad station. The actual time of construction was 54 days, although the total time elapsing from start to finish of the work was 86 days.

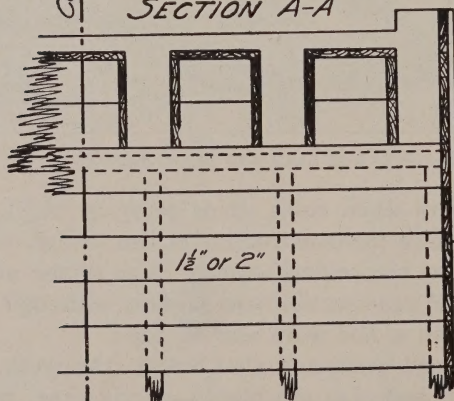
In concreting a combined beam and slab bridge, the work must be continuous so that the beam and slab are placed at one time, thus forming a monolith. This is a very important matter and utmost precautions must be taken to see that it is carried out in the construction of beam and slab bridges.



SIDE ELEVATION



SECTION A-A



SECTION B-B
THROUGH ABUTMENT

FIG. 47.—FORMS FOR DECK OF COMBINED BEAM AND SLAB BRIDGE.

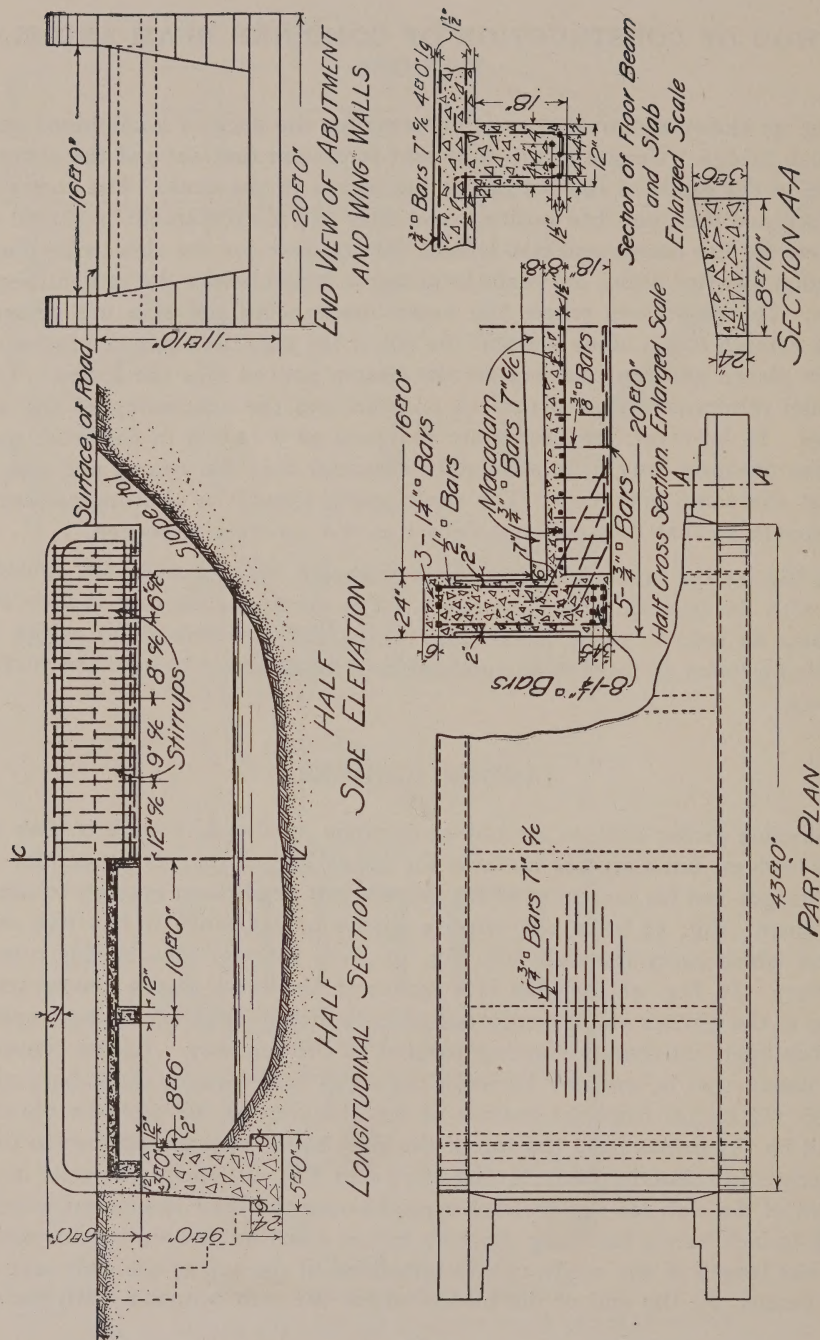
METHOD OF CONSTRUCTION OF COMBINED BEAM AND SLAB BRIDGES.

Fig. 47 shows the arrangement of forms for the deck of a combined beam and slab bridge. Generally the abutment forms are first set and the concrete placed to the grade of the bottom of the beams in the deck. The forms for the deck are then put into position and after the reinforcement is placed the concrete for the beams and slab is laid, the concrete for the slab being placed immediately after filling the beam form below it and before the cement begins to set. In some cases where the beams underneath the slab are designed heavy enough to act alone without the aid of the slab the beam reinforcement is first placed and the concrete for the beams poured into the forms. Then the slab reinforcement is placed in position and the concreting of the slab started. If, however, the beams are designed as T-beams in the more usual and the cheapest way, it is absolutely essential that the beams and slab be laid at the same operation. The deck forms should be thoroughly braced underneath so that they will not deflect as the concrete is poured.

In Fig. 47 the bracing is only partially shown, since it will vary considerably with the location of the structure. The stirrups shown in section A-A can best be held in place temporarily with small wooden strips which are removed as soon as there is enough concrete in the beam to hold the stirrups in place.

GIRDER BRIDGES.

Concrete girder bridges are not so common as slab or combined slab and beam bridges, but they are suitable for spans longer than is proper for the slab bridges and for locations where there is not head room enough to use an arch span. Fig. 44 is in one sense a girder bridge since it has two main girders which carry the slab, but Fig. 48 gives a better idea of this type of structure. In Fig. 48 the slab is 8 inches in thickness at the center and 7 inches at the girders and is reinforced with $\frac{3}{4}$ -inch twisted square bars spaced 7 inches apart on centers running parallel to the roadway. At the center of each panel, that is, midway between the cross floor beams, these bars must be laid $1\frac{1}{2}$ inches from the bottom of the slab, but at the cross-beams they should be $1\frac{1}{2}$ inches from the top of the slab, being bent to conform to these requirements. Another way is that shown in Fig. 48, where the rods in the bottom of the slab are run through straight over the floor beams and another set of $\frac{3}{4}$ -inch bars 4 feet long spaced 7 inches apart on centers is laid parallel with the length of the roadway and imbedded in the top of the slab over the floor beam. At the end of the bridge where the slab connects with the end



floor beam, the rods in the top of the slabs should be bent to extend downward into the floor beam.

The floor beams, which are the cross-beams running from girder to girder, are spaced 10 feet apart on centers and are reinforced with five $\frac{3}{4}$ -inch longitudinal bars and with $\frac{3}{8}$ -inch stirrups. These longitudinal rods must be bent up at each of the floor beams as shown and must extend into the girder.

The main girders have a clear span of 37 feet and a depth of 5 feet. They are reinforced with eight $1\frac{1}{4}$ -inch square bars in the bottom and three $1\frac{1}{4}$ -inch square bars in the top and are provided with vertical stirrups. The stirrups are $\frac{1}{2}$ -inch bars bent U-shaped and placed close together near the ends of the girder and further apart near the center.

The surface of the roadway must be drained and this can best be done by making a slab with a curved upper surface so that the water may run to the gutters and thence through the drain pipes placed in the slab.

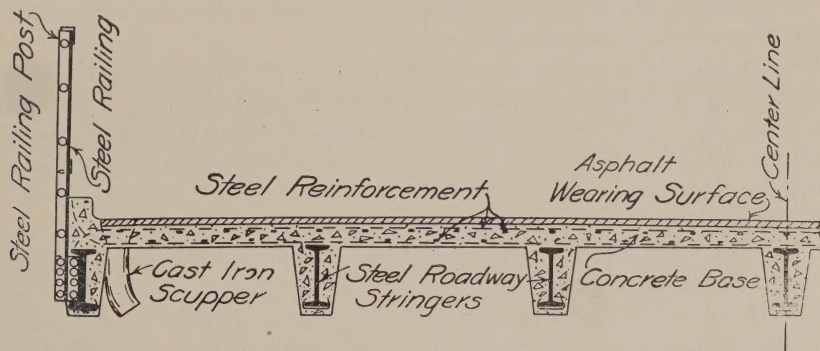


FIG. 49.—REINFORCED CONCRETE ROADWAY FOR STEEL SPANS.

CONCRETE FLOORS FOR STEEL BRIDGES.

On long span highway bridges where steel trusses are necessary, plank flooring has until recently been used, but as this planking only lasts from one to five years there is a demand for something more durable than wood and reinforced concrete slabs on steel beams are being used.

Fig. 49 shows a typical cross section of a concrete slab construction carried on steel I-beam stringers which in turn are supported by the steel floor beams running from truss to truss. A 30-foot roadway without sidewalks is here provided for, but where sidewalks are necessary the construction may be easily modified to suit. The wearing surface of the roadway is shown as asphalt, which usually is laid 2 inches thick on a binder of small thickness. In some cases the binder has been omitted and the upper surface of the concrete left

very rough to give a good union between asphalt and concrete. Proper crown must be given the roadway to take care of the drainage; this being easily done by setting the I-beam stringers on high levels towards the center of the roadway or else by making the concrete slab level and using a greater thickness of wearing surface at the center than at the gutters.

The I-beam stringers should be encased in concrete as shown, for by so doing a stronger floor is obtained and the steel beams are protected against rust. Railing posts made of two steel angles and connected to the outside I-beam by a plate and small angles, give the necessary support to the railings.

COST OF BEAM AND SLAB BRIDGES.

There is considerable variation in the cost of concrete bridges and any data given regarding the cost is at the best only approximate. The cost of a bridge is affected by the span, width, height, character and depth of foundations, the type of structure, the magnitude of the loads to be carried, the style of finish, and by several other elements of a similar nature.

The cost of several reinforced concrete bridges recently built and similar to those shown in this chapter, was \$9.00 per cubic yard for the reinforced concrete where the expense of hauling was considerable, and \$6.75 per cubic yard for abutments without reinforcement. The abutment foundations extended about 3 feet into the ground.

For reinforced concrete bridge work similar to that shown in Fig. 43, the contract price frequently paid by the Pennsylvania State Highway Commission is \$10.00 per cubic yard.

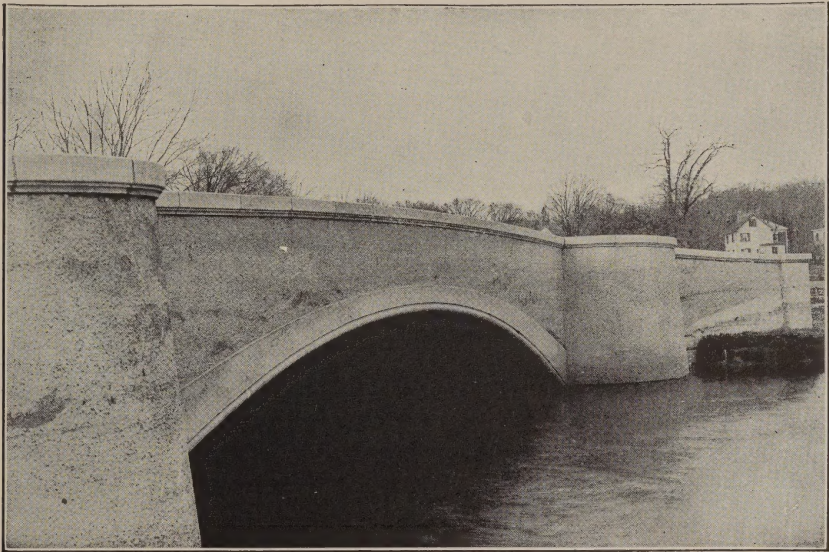
A bridge of 30 feet span similar to the one shown in Fig. 44 and designed by the Illinois Highway Commission cost \$995 not including the crushed stone which was furnished free. The price of the bridge would have been \$1,125 had the contractor furnished everything. There were 90 cubic yards of concrete and 8,600 lbs. of steel in the structure.*

*Illinois Highway Commission Report, 1906, p. 59.

CHAPTER VII.

ARCH BRIDGES.

Arches include that class of curved bridges varying from simple culverts of 5 or 10-foot spans to the wonderful structures like the Walnut Lane Bridge in Philadelphia which has an arch of 232 feet, clear span. The advantage of using concrete in bridges was clearly set forth in Chapter VI. and therefore it is needless to further emphasize in this chapter on arch bridges, its value



AUBURN ST. BRIDGE, MEDFORD, MASS.

wherever ultimate economy, beauty and durability are of importance. Suffice it to say that in many locations a good concrete arch bridge can be built cheaper than a good steel bridge, and when the durability of the concrete and the enormous cost of maintaining the steel bridge are considered there is no question as to which is the better investment for a town or county to make. The concrete structure is more durable, more beautiful, and in every way superior to steel construction for spans of ordinary length. Where the foundations are good, a series of arches may be used in place of a steel bridge with long spans, and the advantages already enumerated for short spans apply equally well in this case. The pressures which the arch exerts on its foundations are

inclined and this pressure or outward thrust must be provided for in the design and construction of the bridge.

PLAIN AND REINFORCED CONCRETE ARCHES.

Arches may be built either with or without steel reinforcing bars; where there is no steel the arch is of plain concrete, and if steel rods or steel in other forms are used to reinforce the concrete the structure is then called a reinforced concrete arch bridge.

Steel reinforcements should always be used in arches, for while it adds very



BRIDGE IN DELLWOOD PARK, JOLIET, ILL.

little to the cost, it increases the strength considerably. In the last few years there has been a remarkable increase in the number of reinforced concrete arch bridges, and they are giving perfect satisfaction. In most cases the quantity of steel used is really very small in proportion to the quantity of concrete, and as this steel is entirely imbedded in the concrete it cannot rust and therefore is not open to the same objections that are raised against steel where it is exposed to the action of the elements. In many arches the cross-sectional area of the steel used is only about $1/100$ of the area of the concrete as measured at the crown of the arch, which is the highest part of the span. This means that for every 100 square inches of concrete there is only 1 square inch of steel at that section.

Under ordinary conditions bridges of spans from 20 or 30 feet to 100 feet can be readily constructed of reinforced concrete, while for even greater spans where the foundations are good, the proper combination of steel and concrete makes a strong, graceful and economical bridge, a type which is being widely adopted in country districts as well as in the larger towns.

HISTORY OF CONCRETE ARCHES.

The first plain concrete arch built was the 116-foot span at Fontainebleau Forest in France, which was finished in 1869, and is known as the Grand Maitre bridge. In the United States the first plain concrete arch of which there is any record was one of 31-foot span built in 1871 in Prospect Park, Brooklyn. The earliest reinforced concrete arch in the United States was constructed in Golden Gate Park in San Francisco in 1889, and several years even before this date concrete bridges reinforced with iron had been built in Europe. This type of construction is not an experiment. It represents the highest art of modern bridge construction. As a material for highway bridges of spans from about 30 feet to 100 feet reinforced concrete has no equal.

As has already been stated, a span of 232 feet has been completed in Philadelphia. The new Rocky River Bridge in Cleveland, Ohio, is being constructed with a span of 280 feet and a proposed bridge in New York City has a span of over 700 feet. These large spans show the rapid development in the art of building bridges with concrete.

TYPES OF CONCRETE ARCHES.

Arches are classified in various ways, but the most simple classification is that which deals with the method of the construction of the spandrels which are the spaces above the upper surface of the arch ring and below the roadway level. These spaces may be either filled in solid with earth filling or they may be left open by supporting the roadway above on slabs and beams, which in turn are supported on columns or cross-walls resting on the arch ring.

Where the spandrel spaces are filled in solid with earth, this earth is prevented from flowing out sidewise by side walls, also called spandrel walls, which run lengthwise of the bridge, one on either side of the roadway. The earth rests directly on the outer surface of the arch ring and the road or street pavement is laid directly on this earth filling. These bridges are said to have solid spandrels.

In the second type, where the spandrels are left more or less open, the roadway is usually laid on a slab of reinforced concrete having a thickness of from 4 to 8 inches which rests upon a series of reinforced beams supported on col-

umns, or upon transverse concrete walls which, being spaced at distances of from 10 to 20 feet lengthwise of the bridge, give the appearance of open spandrels. These columns or walls rest on top of the arch ring.

For small arches the solid spandrel type is the most common, while for the large bridges with spans over 100 feet the open spandrels are better, because they lessen the weight to be carried.

Arches are often also classified as to the style of reinforcement or as to whether there are any hinges used in the arch ring. A hinge is made by inserting a joint in the concrete arch ring, and usually, when they are used, one is

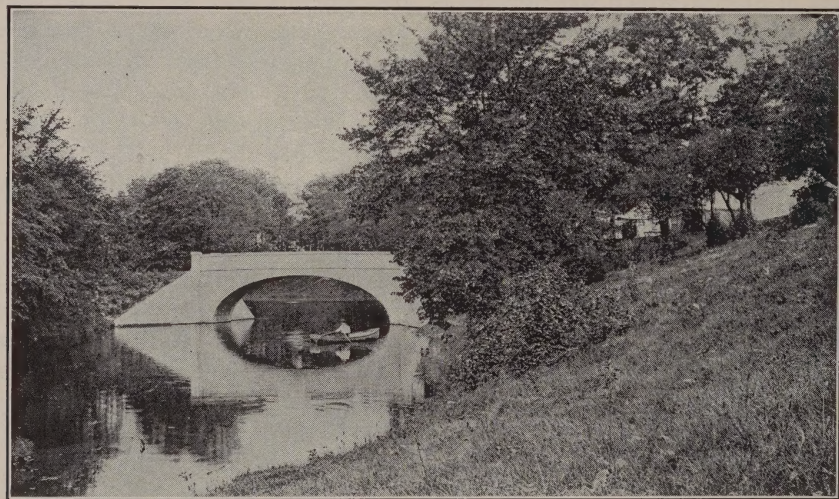


FIG. 50.—ARCH BRIDGE, DELLWOOD PARK, JOLIET, ILLINOIS.

placed at the crown of the arch and also one at each end where the arch ring rests upon the abutment or support. These hinges are made of steel and act very much in principle like the hinges on an open door, that is, the concrete arch ring can move a little by turning around the steel hinges. This movement is of course very small. Hinges are used with an idea of simplifying the design of the arch, but they have been employed in only a few cases in the United States.

PREPARATION OF PLANS.

An arch bridge is too important a structure to be placed in charge of an inexperienced man. The only safe way is to employ a competent engineer to prepare plans and specifications and to superintend the construction. Before

the contract for the bridge is let, the plans should be complete and should show not only the principal dimensions of the structure, but they should also show all important details which may in any way affect the strength or the cost. Unless the plans and specifications are complete and accurate, unnecessary delays in construction and extra charges for changes and additions will inevitably occur. If the engineer is not to be on the ground continually during the construction, he should be allowed a competent assistant or inspector whose duty it should be to see that the plans and specifications are followed and that the work is carried on in a proper manner.

DESIGN FOR A 40-FOOT SPAN.

Fig. 51 shows a design for a reinforced concrete highway arch for a 40-foot span with a rise of 8 feet. The principal parts are the arch ring, the spandrel or side walls, the abutments, the wing walls, the parapets and the earth filling. The cross section at crown shows a 20-foot roadway with a 6-foot sidewalk on either side. At the crown of the arch the earth filling has a thickness of 18 inches at the center of the roadway.

The arch ring is 12 inches thick at the crown and 2 feet 6 inches thick at the abutments, the latter being the radial not the vertical thickness. The dimensions of the abutments are shown in the drawing and have been determined on the assumption that the soil under the foundations is good compact sand and gravel or other similar materials capable of safely sustaining 4000 to 6000 lbs. per square foot.

The arch ring is reinforced with round medium steel rods $\frac{3}{4}$ inch in diameter running lengthwise of the span, arranged in two layers, one layer 2 inches in from the outer curved surface of the concrete ring and the other 2 inches from the inner curved surface. These layers, therefore, are 8 inches apart at the crown and 2 feet 2 inches apart at the abutments. The rods in each layer are 8 inches apart on centers as shown in the cross section.

In addition to the $\frac{3}{4}$ -inch rods there are two sets of $\frac{1}{2}$ -inch diameter rods running at right angles to the length of the roadway as shown in the one-half longitudinal section. In each layer the $\frac{1}{2}$ -inch rods are 15 inches apart on centers. Stirrups made of $\frac{3}{8}$ -inch diameter round rods are frequently used in bridges of this type to connect the outer layer with the inner. They should be hooked at the outer and inner ends to pass around the transverse and longitudinal rods at their intersections. In the bridge shown, this arrangement would space them 15 inches apart. Where no stirrups are used, the transverse and longitudinal rods should be connected by wires at their intersections.

Where the design calls for rods longer than can be obtained in one length, splices must be used and this can be done by simply lapping the two bars to

be spliced a distance equal to 20 diameters of the rod if it has deformed surfaces or 30 diameters if it has smooth surfaces. Sometimes the rods are lapped and then wound with heavy wire. Some designers thread the rods and splice them by means of sleeve nuts, but usually it is sufficient to lap the rods as indicated.

As shown in the cross section at the crown, Fig. 51, six $\frac{1}{2}$ -inch diameter rods should be placed in the parapet wall between the expansion joints.

The design shown is suitable for ordinary highway traffic.

EXPANSION JOINTS.

Each spandrel wall and parapet is provided with an expansion joint at the abutments. This is to allow for the change in length of these parts due to changes in temperature. Concrete changes its length about $\frac{3}{8}$ -inch for every 100 feet of length due to the change in temperature from a mean temperature to extreme heat or to extreme cold in a climate such as that of New England, Michigan or similar sections. Unless the wall is properly reinforced, expansion joints should be left at distances apart not much over 40 feet or even less to prevent cracking due to these changes in temperature. These joints should be made from the upper surface of the arch ring to the top of the parapet and should be made wedge-shaped or dove-tailed so that one part fits into the other.

REINFORCED CONCRETE ARCH, ELM STREET, CONCORD, MASS.

Figs. 52 and 53 show a highway bridge of 75 feet clear span built of "ATLAS" Portland Cement in Concord, Massachusetts, by the Massachusetts Highway Commission. The rise of the arch is 12 feet or about $\frac{1}{6}$ of the span length. At the crown the arch ring is 16 inches in thickness and increases towards the abutments as shown.

The reinforcement in the arch ring consists of 1-inch longitudinal twisted steel bars spaced 17 inches apart on centers and $\frac{1}{4}$ -inch transverse twisted steel bars spaced 24 inches apart on centers. The centers of the 1-inch rods are $2\frac{1}{4}$ inches from the face of the concrete and these rods are in lengths of about 16 feet lapped 40 inches at each splice as shown in Fig. 55. Reinforced side walls braced with counterforts shown in Fig. 53 serve to retain the earth filling. Although there is a comparatively small amount of concrete used in the construction of this type of wall, the saving due to this is probably more than offset by the increase in cost due to the expensive forms necessary for the counterforts. Several sections of these side walls are shown in the upper right hand corner of the drawing over the half section of the arch, and the locations of these sections are indicated by distances on the half section and

by letters upon the plan of the arch. The steel in the side walls consists of $\frac{5}{8}$ -inch horizontal rods spaced 12 inches apart on centers near the bottom and $\frac{1}{2}$ -inch rods spaced 24 inches apart on centers near the top of the wall. In the coping there are also two $\frac{1}{4}$ -inch longitudinal rods. The counterforts are provided with tie rods as indicated.

As shown in Fig. 53, the coping overhangs the face of the arch ring and the face of the wing walls by $1\frac{1}{2}$ inches, the faces just mentioned being in the same vertical plane; the spandrel walls are set back $1\frac{1}{2}$ inches from the face of the arch ring, hence 3 inches back from the surface of the coping. This gives a neat design and one which is easily carried out.

Four hundred and fifty-eight cubic yards of concrete were used in this structure.

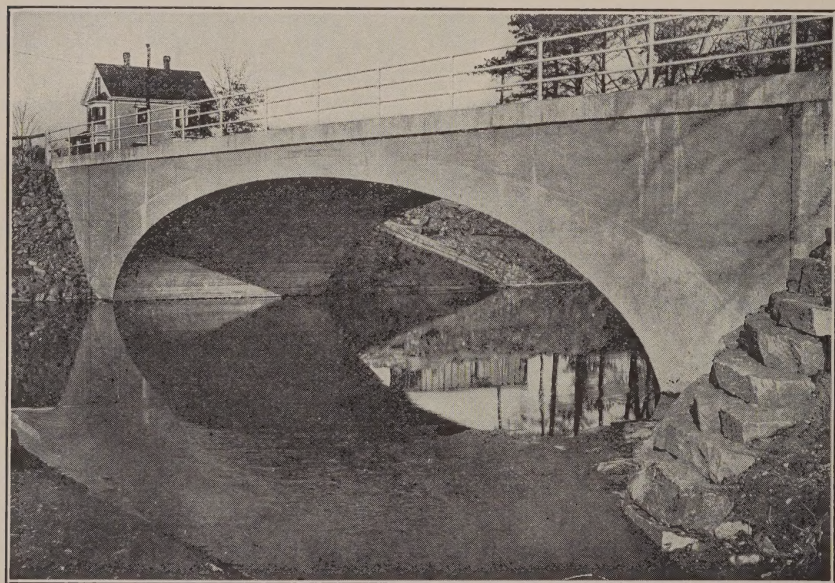


FIG. 52.—ARCH BRIDGE WITH SPAN OF 75 FEET, ELM STREET, CONCORD, MASS.

Fig. 54 on page 110 is a view taken just after the falsework and centering were in place and before the lagging was placed on the centering. The photograph on page 110 shows the arch ring under construction with the longitudinal rods partially imbedded in concrete. One of the small transverse rods may be seen just beyond the top of the transverse stop boards. These stop boards serve as temporary forms for the concrete and also as spacers for the longitudinal rods. After these boards are removed the next section of the concrete

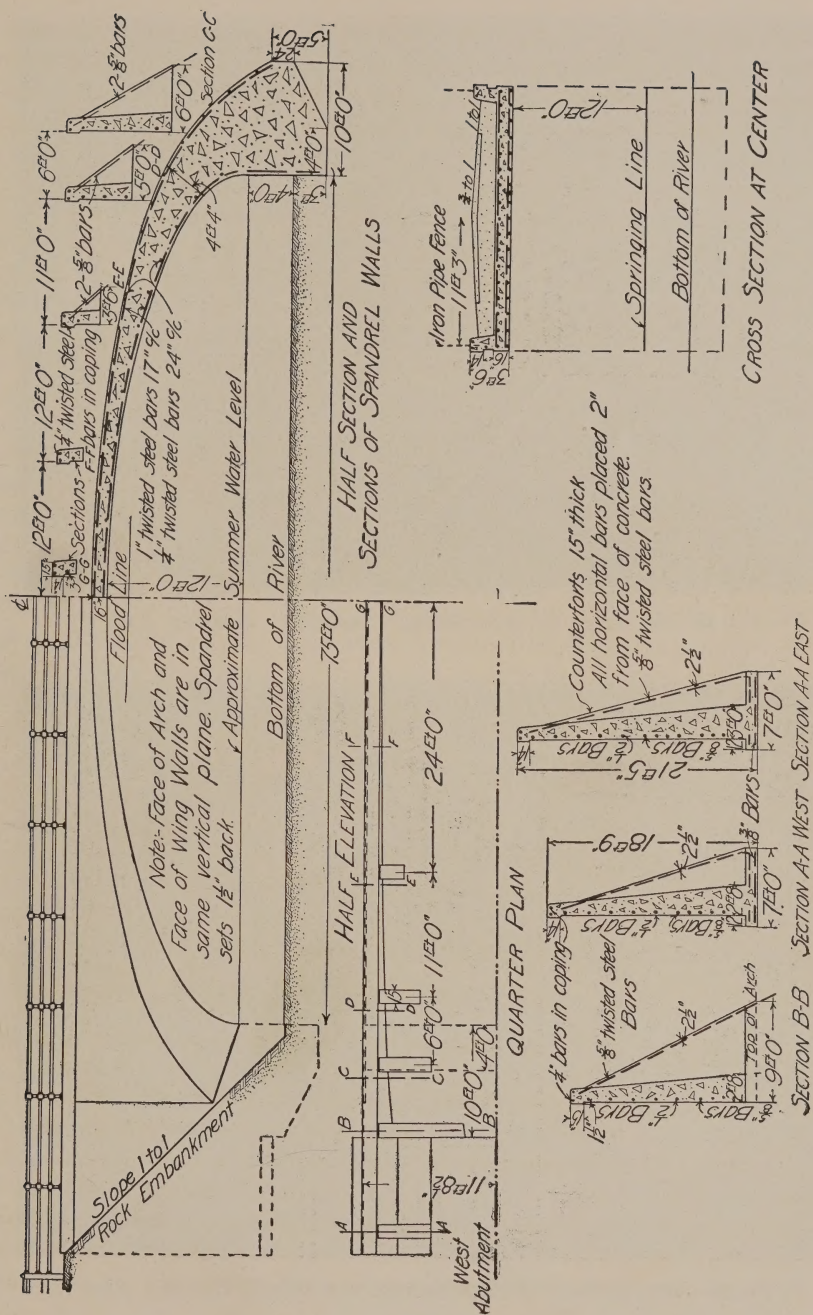


FIG. 53.—ARCH BRIDGE WITH SPAN OF 75 FEET, ELM STREET, CONCORD, MASS.

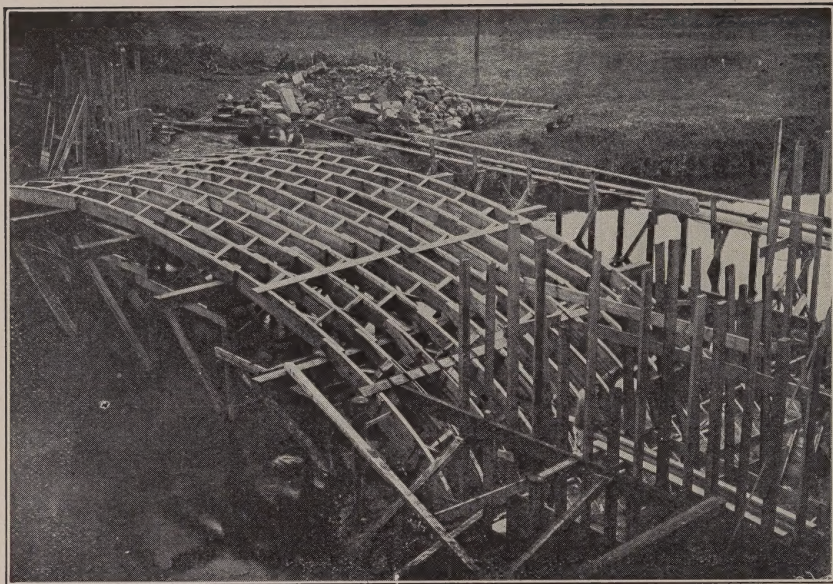


FIG. 54.—CENTERING OF ARCH BRIDGE, ELM STREET, CONCORD, MASS.

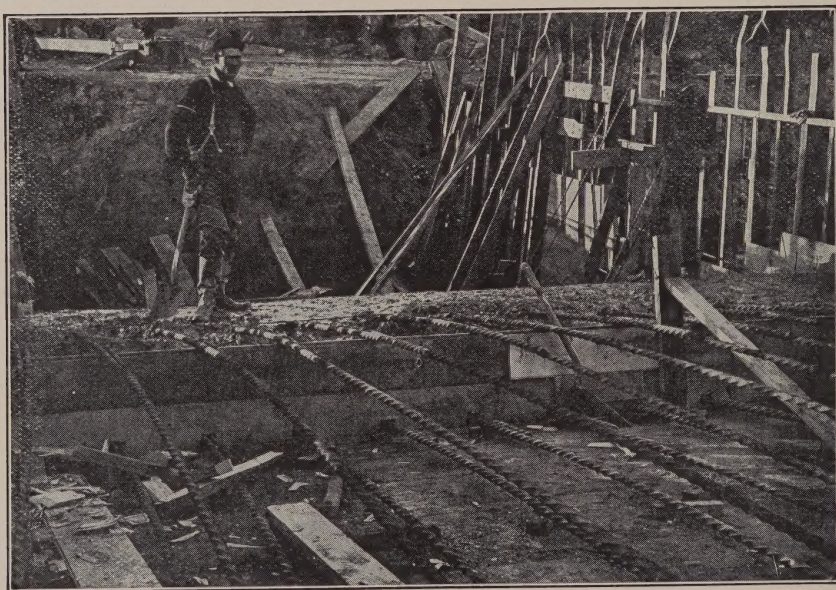


FIG. 55.—CONSTRUCTION OF ARCH BRIDGE, ELM STREET, CONCORD, MASS.

for the arch ring is deposited against the finished section. The form of arch here shown is suitable for locations where the foundation is of the hardest material, like hard pan or rock.

FALSEWORK AND CENTERING.

The falsework and centering, Fig. 56, constitute that part of the temporary wood work which supports the concrete while it is being laid and until it has hardened. The falsework consists of vertical timbers braced transversely and longitudinally upon which rest the centering or curved platform forming the support for the concrete arch ring. The vertical supports may be either piles driven into the ground or river bottom underneath if the bottom is soft, or framed trestle bents resting on horizontal timbers if the bottom is hard. The piles must be placed close enough to carry the weight above with practically no settlement and must be braced with 2 by 8-inch or 2 by 10-inch diagonal timbers spiked or bolted to the piles.

Transversely to the length of the bridge and spiked or bolted to the tops of the piles, a cap must be set and upon these caps rest wooden wedges supporting the weight of the centering above.

The centering consists usually of a set of caps or cross timbers resting on the wedges above the pile caps, some longitudinal stringers notched on and supported by the upper caps and finally of a closely laid flooring or lagging resting on the stringers. The caps for the centers are usually 10 by 10 inch or 12 by 12 inch timbers. The stringers are of varying size, depending on the distance between piles and the weight to be carried. For arches having spans up to 100 feet, these stringers are from 2 to 4 inches wide and from 12 to 14 inches deep, spaced from $1\frac{1}{2}$ to 3 feet apart on centers. The upper surface of the stringers must be curved to fit the curvature of the under surface of the arch; this is frequently done by nailing a curved piece to the top of the stringers as in the centering of the Concord Arch in Fig. 54 and also in Fig. 56. The stringers must be braced to one another by 1 by 6-inch bridging as is common in ordinary house floors.

Lagging, consisting of $\frac{7}{8}$ -inch tongued and grooved pine or 2-inch spruce with beveled edges, must be nailed to the stringers and must be planed on the top side to give a smooth finish to the under surface of the arch ring. Sometimes where the stringers are quite far apart 4-inch lagging is used.

PLACING CONCRETE.

Before concreting is begun, the forms for the foundations and wing walls should be in place and thoroughly braced and the steel reinforcement set and wired in place. The forms and steel for the spandrel walls and the arch ring

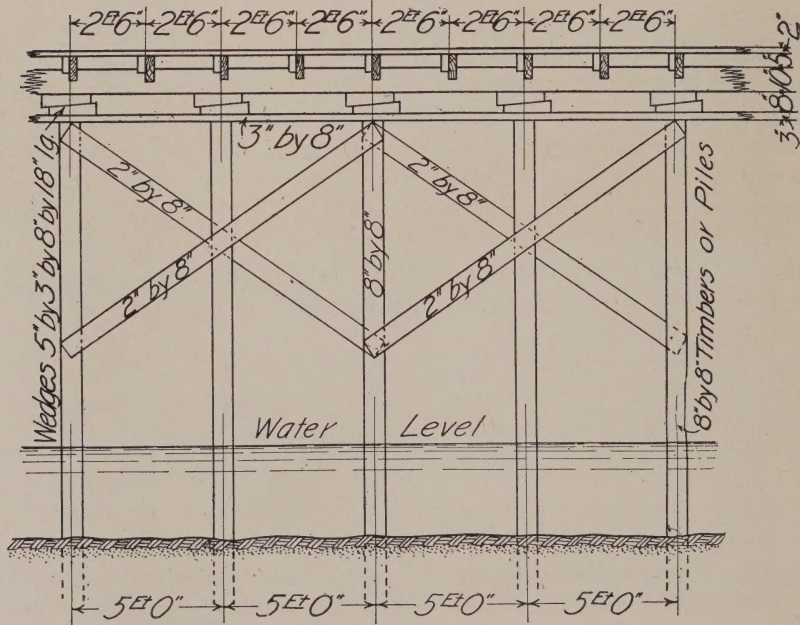
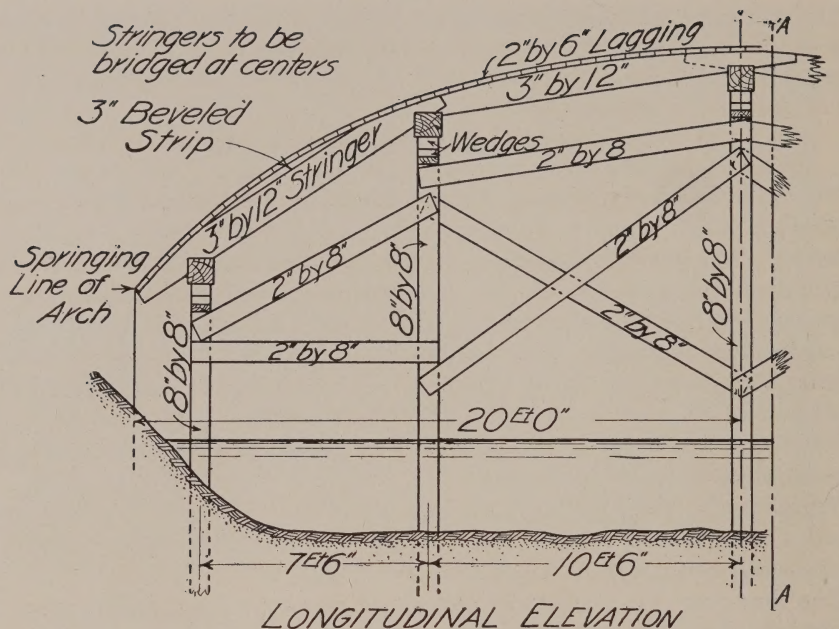


FIG. 56.—FALSEWORK AND CENTERING FOR ARCH WITH SPAN OF 40 FEET.

may be placed while the concrete is being deposited for the foundations. As soon as the concrete in the foundations is up to the arch, the arch may be begun and laid in one or two days.

First, the arch ring may be divided longitudinally into parallel rings or sections having a width of from 3 to 5 feet, or even more if the span is not too large, and one of these sections laid at a time. This is generally the best plan to follow.

Or, secondly, the arch ring is divided into sections as shown in Fig. 55, which shows the Concord Arch being laid in large, separate blocks across the

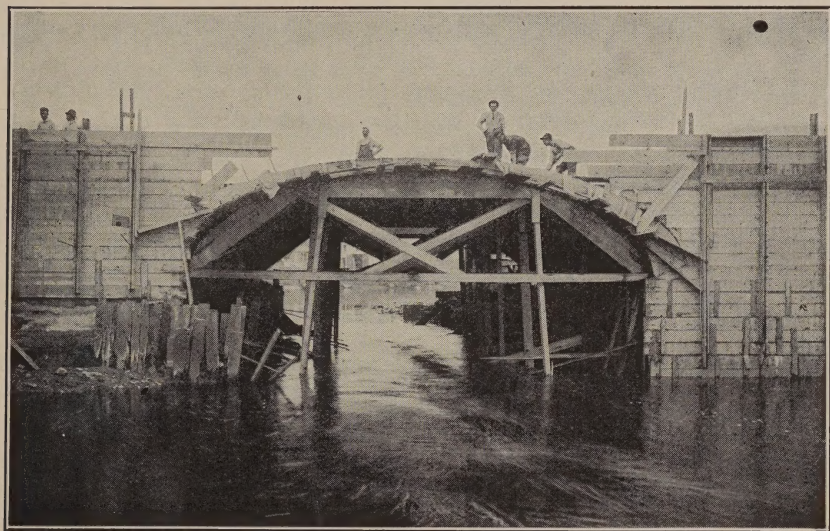


FIG. 57.—CENTERING FOR ARCH IN PLACE.

bridge, having a width equal to that of the arch ring and a length equal to a fraction of the span length.

Whichever of these methods is used, care must be taken to avoid undue settlement or distortion of the centers as the concreting progresses. If the second method of laying concrete is used, that is, in large transverse blocks, the work is usually begun at each abutment at the same time, and if the centering is not well supported underneath it will rise at the crown, due to the weight at the two ends. To avoid this the best way is to begin concreting at the two abutments and as this work progresses load the centering at the crown temporarily, adjusting this load if needs be to keep the centers in proper position. The loading at the crown is frequently done by laying a part of the arch ring there

after a part is laid at each abutment. Then the spaces between these blocks are filled in.

For small arches the entire ring can be laid in one day's work, and of course this should be done whenever possible.

EARTH FILLING.

After the concrete is placed in position and thoroughly hardened and before the centers are removed, the earth filling should be added. As the earth is placed, it should be compacted by ramming or rolling, and even if the centers are still in place it is better to deposit the earth in layers over the whole length of the span so that the arch is loaded nearly uniformly till the entire filling is in place.

If the filling is placed after the centers are removed, it is absolutely necessary to place the earth uniformly over the span length and not pile a large weight on one side leaving the other side unloaded.

In case the finished roadway is to have a surface such as macadam or concrete, great care should be taken in compacting the earth filling, for otherwise settlement will take place in the filling and the roadway surface will also settle.

STRIKING CENTERS.

By striking centers is meant the lowering of the centers so that the arch becomes self supporting. The centers are usually lowered by removing the wooden wedges already mentioned under the head of Falsework and Centering. These wedges, Fig. 56, placed between the caps of the falsework and those of the centers, can be removed by a sledge hammer, thus lowering the centers. Care must be taken to lower the centers gradually and without jarring the structure by allowing a part to get its load suddenly.

SURFACE FINISHING.

In many structures the appearance of the surface of the finished concrete is of no importance, but most structures, such as bridges, which are constantly exposed to view, need some treatment to render the outer surfaces neat in appearance. Oftentimes the structure is such that proper selection of good tongued and grooved planking smoothly laid, together with care in placing the concrete against the forms is all that is required to give a fairly presentable surface. This surface is obtained by simply forcing a spade down the side of the forms and pushing back the stones so that the mortar will flow against the face of the forms and fill all stone pockets or voids.

If a better finish is desired, good results can be obtained by removing the

forms before the concrete has set very hard, generally from 12 to 48 hours, depending upon the cement, weather and amount of water used in mixing, and after floating the green concrete with water by rubbing the surface with a circular motion with carborundum bricks or with bricks composed of 1 part "ATLAS" Portland Cement to 2 parts sand. If the concrete can be worked when quite green, a very satisfactory finish can be obtained by rubbing the surface with stiff wire brushes.

When the surface of the concrete has set so hard as to prevent its being treated by rubbing with a brush, it still may be surfaced with a carborundum block, or an excellent finish may be gained by picking the concrete surface with a hand or pneumatic tool after the forms are removed. If further treatment is deemed necessary the tooled surface may be washed with a weak solution of acid and then with an alkali solution to neutralize the effect of the acid.

If a very smooth surface is desired, a veneer of mortar is sometimes placed between the main body of the concrete and the forms. This mortar facing is usually composed of 1 part "ATLAS" Portland Cement to 2 or 3 parts sand and may be applied in several ways. Perhaps the cheapest and easiest method is to trowel a layer of mortar an inch in thickness against the face of the forms and immediately deposit the concrete against it, thus causing the two parts to become thoroughly united. Another method is to hold the concrete away from the forms about 1 inch by means of sheet iron plates while the mortar is being placed between the plates and the forms.

A granolithic finish is given the exposed surfaces of bridges in Philadelphia by applying a 1-inch layer composed of 1 part cement to 2 parts sand to 3 parts broken stone to the inner surface of the forms slightly in advance of the concrete body. After 24 or 48 hours the forms on the faces of the bridge are removed and the concrete surface is immediately rubbed, using a wood block with sand and water and then washing with clean water.

Plastering on concrete surfaces exposed to the weather should be avoided as the plaster is sure to peel off and leave the surface in an unsightly condition unless extraordinary precautions are taken. If plastering is unavoidable the forms must be wet instead of greased. The surface of the concrete should be picked or bush hammered to make it rough, thoroughly wet and then covered with a thin coat of neat cement paste upon which the plaster must be applied in as thin a layer as possible and before the neat cement paste has set.

COST.

There are so many variable items in bridge building that to give accurate figures regarding costs is practically impossible. Frequently the cost is given for a bridge based on a cubic yard of concrete as a unit, while in other cases

the cost per horizontal square foot of roadway surface is taken as a unit. In a paper read by Mr. Henry H. Quimby before the National Association of Cement Users in Cleveland, Jan. 11-16, 1909, he states that the average cost per cubic yard of 18 concrete bridges recently built in Philadelphia was \$9.75, with a minimum of \$6.50 and a maximum of \$11.25 per cubic yard. Basing the cost on a horizontal area equal to the clear span times the width, he gives as an average cost for these bridges \$6.50 per square foot, with a range of from \$3.11 to \$9.74 per square foot. These figures include all the concrete in the arches and abutments.

The cost of the O'Connor Street reinforced concrete skew arch bridge in Ottawa*, Canada, was \$8.02 per cubic yard as an average cost for the total of 620 cubic yards including some plain and some reinforced concrete. The cost of the reinforced concrete was \$9.80 per cubic yard. This bridge has a span of 20 feet; a length of 46 feet; thickness at crown 18 inches; a rise of 4 feet 10 inches.

The cost of two concrete arches, one of 50-foot and the other of 44-foot span, built by the Pennsylvania State Highway Department in 1907 is given by Mr. G. A. Flink† as \$7.50 per cubic yard for the 44-foot span which contains 243 cubic yards of concrete, and \$9.50 per cubic yard for the 50-foot span containing 268 cubic yards. The 50-foot span has a rise of 6 feet 9 inches, which is quite small for a bridge of this length.

*The Concrete Review, Vol. 3, Nov. 1, 1908, p. 23.

†Good Roads Magazine, April, 1908, p. 111.

CHAPTER VIII.

RETAINING WALLS.

Retaining walls are frequently required to hold back an adjoining mass of earth from sliding upon a highway or for supporting the lower side of a highway on a side hill. In fact, where the highway is cut in the side of a hill it may be necessary to use a retaining wall on the up-hill as well as the down-hill side of the road. Walls are also necessary in many cases where an embankment is confined to a limited width as, for instance, where the highway is carried up to and over a railroad on an inclined embankment which is confined on either side of the roadway by a wall running parallel with the roadway.

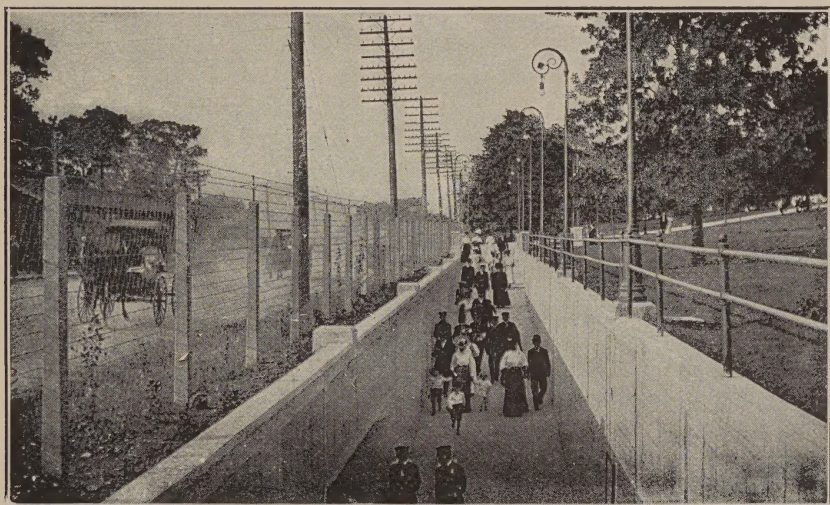


FIG. 58.—RETAINING WALLS AT DELLWOOD PARK, JOLIET, ILL.

Fig. 58 illustrates a use of retaining walls which is quite common. The two walls shown hold back the earth on either side of an inclined passage way leading to the subway entrance in Dellwood Park, near Joliet, Illinois. In the left of the picture is a highway and on the right the park. These walls were built of concrete made of "ATLAS" Portland Cement.

Retaining walls are needed in many places in addition to the uses already cited.

Concrete retaining walls are built either with or without steel reinforcement and they have come into prominence because they are more economical than the stone masonry walls so universally used until a few years ago. Concrete has already demonstrated its usefulness as a material for wall construction, not only because of its low first cost, but also because no maintenance is necessary. A stone retaining wall must be pointed from time to time to keep the joints closed or the masonry will soon be disintegrated by frost. Concrete walls have practically no joints and hence no maintenance charges.

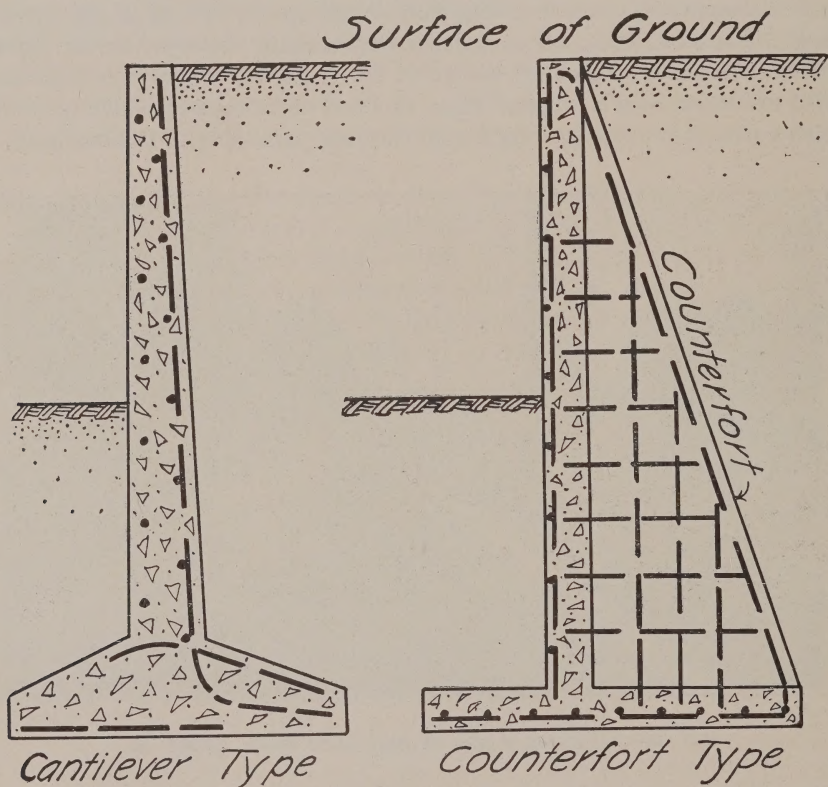


FIG. 59.—TYPES OF REINFORCED CONCRETE RETAINING WALLS

KINDS OF RETAINING WALLS.

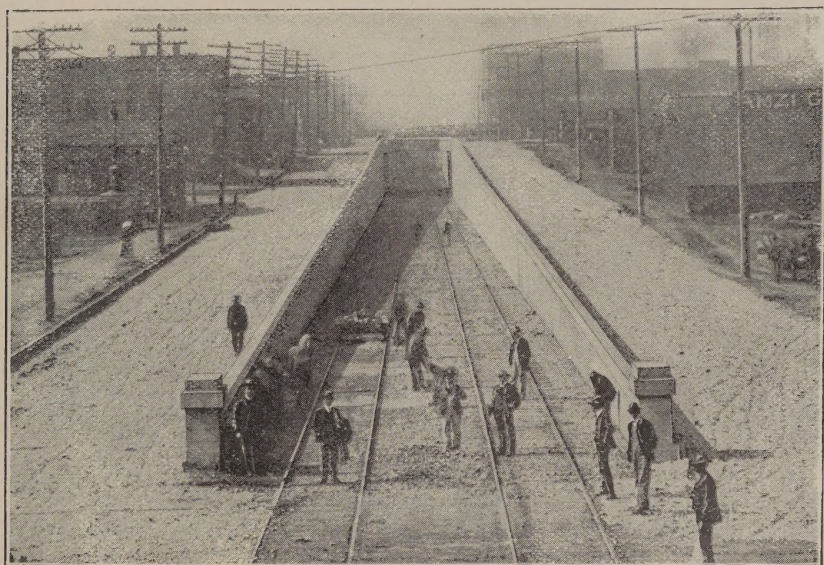
Retaining walls are built in the form of thin reinforced concrete walls or as gravity walls of plain concrete containing little or no steel reinforcement.

Gravity walls are designed to withstand the earth pressure behind them by

being made sufficiently heavy to prevent sliding or overturning. They do not utilize the weight of the earth behind them to add to their strength.

Reinforced concrete walls, however, depend to a considerable extent on the earth sustained to add to their stability. The earth behind the walls presses against it, but at the same time the wall is of such a shape that this earth pressure helps to some extent to prevent sliding or overturning. Reinforced walls can be made much thinner than gravity walls and for this reason reinforced walls are usually cheaper.

Reinforced walls as usually built consist of a thin vertical wall attached to a horizontal base and braced either by counterforts on the back or by but-



RETAINING WALLS, BIRMINGHAM, ALA.

tresses on the front side. In more recent designs no buttresses or counterforts are used and the wall then is a vertical slab of reinforced concrete attached to a horizontal base.

Fig. 59 illustrates the two more usual types of reinforced concrete walls, cantilever and counterfort types.

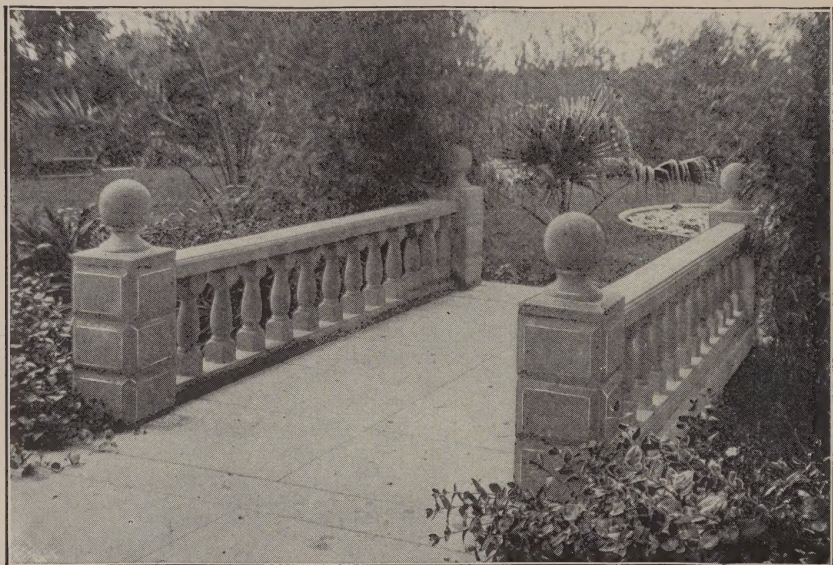
Buttresses projecting out in front of the wall are not often used, for they take up too much space which in many cases must be utilized for other purposes. In addition they give a very unsightly appearance to the face of the wall.

Counterforts are thin walls running back into the earth behind and serve to

brace the main vertical wall. They are quite frequently used, but the inverted T-shaped cantilever type is so much more easily and cheaply constructed that it should be used unless the wall is at least 18 feet high above ground, in which case the counterfort type may be more economical. Counterforts rest on and are connected to the horizontal base of the wall, and, being reinforced with steel bars, they really act as ties on the back of the wall.

GRAVITY RETAINING WALLS.

With a gravity type of construction, the weight of the wall is relied upon



BEAM BRIDGE ON PRIVATE ESTATE, REDLANDS, CAL.

to sustain the earth pressure and the wall must not only be of sufficient weight but also must have the proper shape.

In the construction of retaining walls of any shape or kind, care must be taken to get good foundations. If the material under the wall is compact sand or gravel, there should be no trouble with the foundation. In some cases, where it is necessary to build a wall on rather soft ground, the sub-soil must be thoroughly drained and in addition it must be compacted by ramming sand or gravel or stone into it. Where the soil is very soft, piles are required to sustain the weight of the wall with the earth pressure behind it. In building walls upon rock which has an inclined surface, this surface must be made horizontal, stepped, or roughened by blasting to prevent the wall from sliding down the

inclined rock surface. Several large retaining walls have failed because this was not regarded. By taking the precautions just mentioned no trouble will be experienced.

Gravity walls are usually made with a coping on top of the main body of the wall. The front or exposed face of the wall is sometimes made vertical and is sometimes given a batter, that is slightly inclined, and the back side of the gravity wall is either sloped or stepped so that the base of the wall is thicker than the top. A slight batter on the face adds to the appearance of the construction, but too large a batter makes the wall look as if it were leaning backwards. For low walls, say those under 12 or 15 feet in height, the face may be made vertical, although a batter of $\frac{1}{2}$ inch per foot while not absolutely necessary is desirable. In heavy construction this batter is sometimes exceeded, but should never be more than $1\frac{1}{2}$ inches per foot.

COPINGS.

The coping for a gravity wall should overhang the front surface of the wall 2 or 3 inches and should be from 12 to 18 inches deep, depending on the height of the wall. For heights of less than 15 feet a coping 12 inches deep should be used, while for walls of greater heights the coping should be 15 to 18 inches deep.

The top surface of the coping should be sloped backward so that dirt will not be washed towards the front edge of the coping and thus will not drop on the front face of the wall and discolor it. The back edge of the top surface should be $\frac{1}{4}$ inch below the front edge. The front surface of the coping should be vertical and the back is sometimes, though not always, made so. The two upper corners and the front lower corner should be beveled off so that there will be no sharp corners of concrete exposed. This beveling can be best done by nailing in the forms strips of molding having triangular cross sections.

Copings may be laid on top of the wall after the concrete in the wall is hardened or they may be laid at the same time as the body of the wall. The top and front surface of the coping to a depth of 2 inches may be made of a mortar of 1 part "ATLAS" Portland cement and 2 parts clean sand laid between the forms and the inner body of the concrete. In no case should the mortar be plastered on the concrete after the latter has hardened. The upper surface of the coping should be "floated" or finished in the same manner as is the wearing surface of side walls.

Copings should be laid with vertical joints to match the vertical joints in the body of the retaining wall.

FORMS FOR GRAVITY WALLS.

In Fig. 60 is shown a good arrangement for the construction of forms for a gravity wall and a movable form* for building the coping in sections 12 feet long is likewise shown in the same figure.

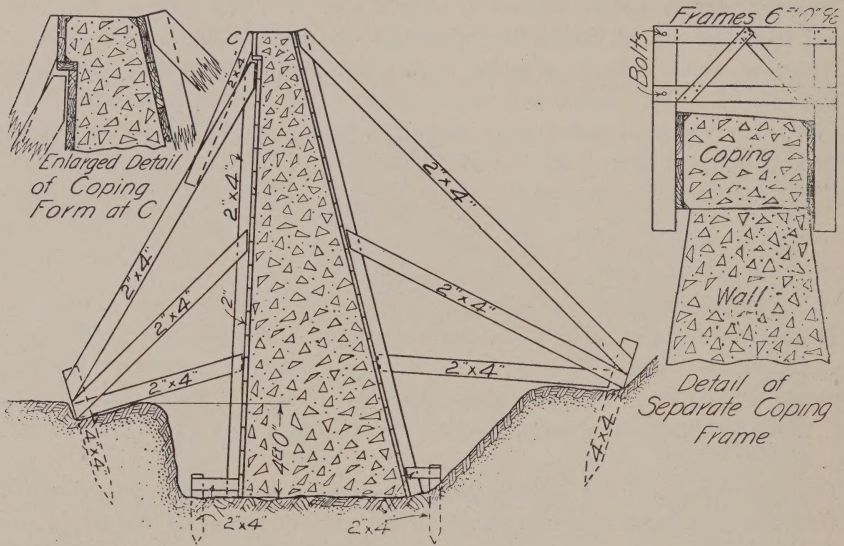


FIG. 60.—FORMS FOR GRAVITY RETAINING WALL

The forms for the wall consist of sheeting made of $1\frac{1}{2}$ or 2-inch lumber braced by 2 by 4-inch studs and 2 by 4-inch inclined struts spiked to a post driven in the ground. The front and back forms are separated by means of 2 by 4-inch braces or by $\frac{1}{2}$ -inch bolts running through both of them and also through a piece of 1 or $1\frac{1}{2}$ -inch pipe between them, these pipes serving as spacers for the two forms as well. Wires are sometimes used in place of the bolts, but they are apt to stretch or break and bolts are better.

In placing concrete in the forms, care must be taken to avoid any longitudinal joints on the front face of the wall. To this end the wall should be divided into short sections such that the work in one section can be completed without leaving any horizontal joints. Of course in such an arrangement the forms have to be planked up at the outer end of the section, these end boards being removed when the adjoining section is begun.

*"Engineering News," Vol. L., July 9, 1903, p. 37.

The movable form shown in Fig. 60 is useful where the coping is built after the body of the wall. These forms are made in sections 12 feet in length with 3 of the bracing frames, one at each end and one in the middle of the 12-foot section. They are held in place on top of the wall and the coping concrete is deposited within the form and after the concrete has set the bolts at the points shown are removed so that the forms can be taken off.

DIMENSIONS OF GRAVITY WALLS.

The accompanying table shows dimensions and quantities of concrete for gravity walls shown in Fig. 60, with heights varying from 6 feet to 20 feet, the heights being the difference in elevation between the upper and lower levels of the earth.

DIMENSIONS AND QUANTITIES OF GRAVITY RETAINING WALLS

Height Above Ground Level, Feet	Width of Base		Total Height Feet	Batter on Face Inches	Cubic Yds Con- crete in Wall 1 Foot Long
6	2 ft	3 in.	10	4 $\frac{1}{2}$	0.64
8	3 "	0 "	12	5 $\frac{1}{2}$	0.92
10	3 "	9 "	14	6 $\frac{1}{2}$	1.26
12	4 "	6 "	16	7 $\frac{1}{2}$	1.65
14	5 "	3 "	18	8 $\frac{1}{2}$	2.10
16	6 "	0 "	20	9 $\frac{1}{2}$	2.61
18	6 "	9 "	22	10 $\frac{1}{2}$	3.17
20	7 "	6 "	24	11 $\frac{1}{2}$	3.78

The bottom of the wall should in all cases go well below the frost line. Four feet has been taken in this case, though of course this will vary with different localities. Four feet, however, is usually enough, even in the coldest climates. The coping is shown 12 inches high and 18 inches wide on top and the top surface should have at least a $\frac{1}{4}$ -inch slope towards the back.

The width of the base must of course be made larger as the height of the wall increases. For highway work where the upper surface of the ground is horizontal and level with the top of the wall it is customary to make the base $\frac{3}{8}$ of the height of the wall, the height being taken as the distance between the upper and lower levels of the ground, thus: if the height of the wall is 20 feet the base would be $\frac{3}{8}$ of 20, that is 7 $\frac{1}{2}$ feet. The batter on the front face is $\frac{1}{2}$ inch per foot of vertical distance under the coping, that is, $\frac{1}{2}$ times 23 or 11 $\frac{1}{2}$ inches. In this case the amount in 1 foot length of wall is 3.78 cubic yards.

Where the earth to be sustained is rather wet and slopes up from the top of the wall instead of being horizontal, the thickness of the base should be $\frac{1}{2}$ of the height of the wall.

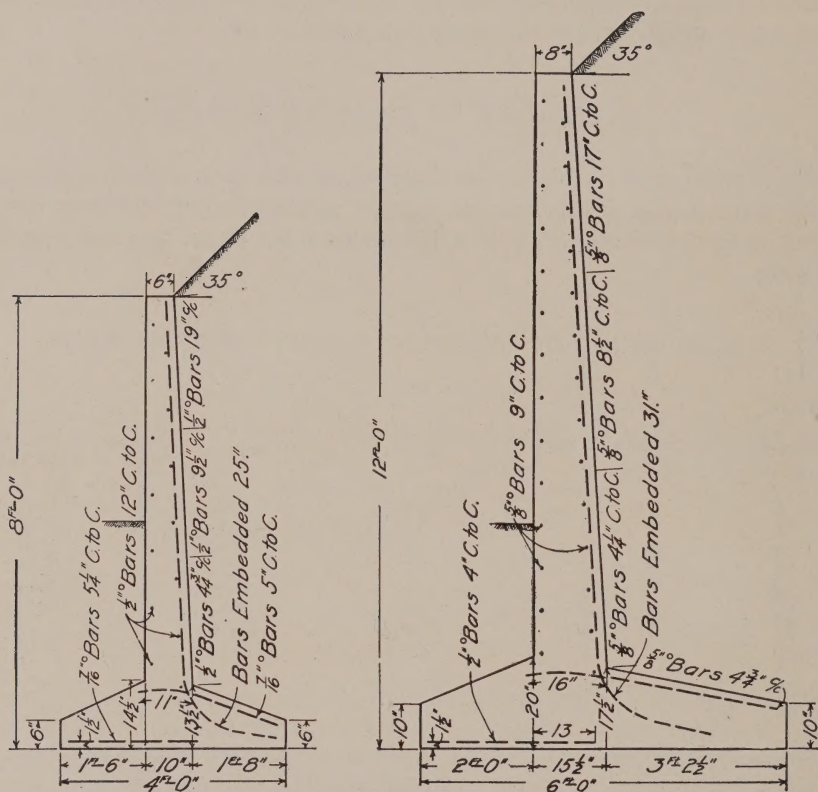


FIG. 61.—SECTIONS FOR REINFORCED RETAINING WALLS.

REINFORCED RETAINING WALLS.

The cantilever retaining walls shown in Fig. 61 consist of a vertical slab of reinforced concrete attached to a reinforced concrete base, the whole section being really an inverted T. The figure shows designs for 2 walls, one for a total height of 8 feet, the other 12 feet. In severe climates the bottom of these walls should be placed 4 feet below the surface of the ground in front of them, thus making the visible height of the finished wall 4 feet and 6 feet respectively. Maximum pressure on soil from these walls is 2 tons per sq. ft.

Great care must be taken to place the steel reinforcement in the exact positions called for by the drawing. In each wall the reinforcement consists of 5 sets of reinforcing bars. In the base of the 12-foot wall there is one set of horizontal half-inch round bars spaced 4 inches apart and $1\frac{1}{2}$ inches above the lower edge of the base. Near the upper surface of the base there is a set of $\frac{5}{8}$ -inch round rods spaced $4\frac{3}{4}$ inches apart and slightly inclined as shown in the drawing. In the vertical parts of the wall there are two sets of $\frac{5}{8}$ -inch round horizontal rods, one set near the front face and one near the rear face of the wall. Also in the vertical part there is a set of $\frac{5}{8}$ -inch round vertical rods



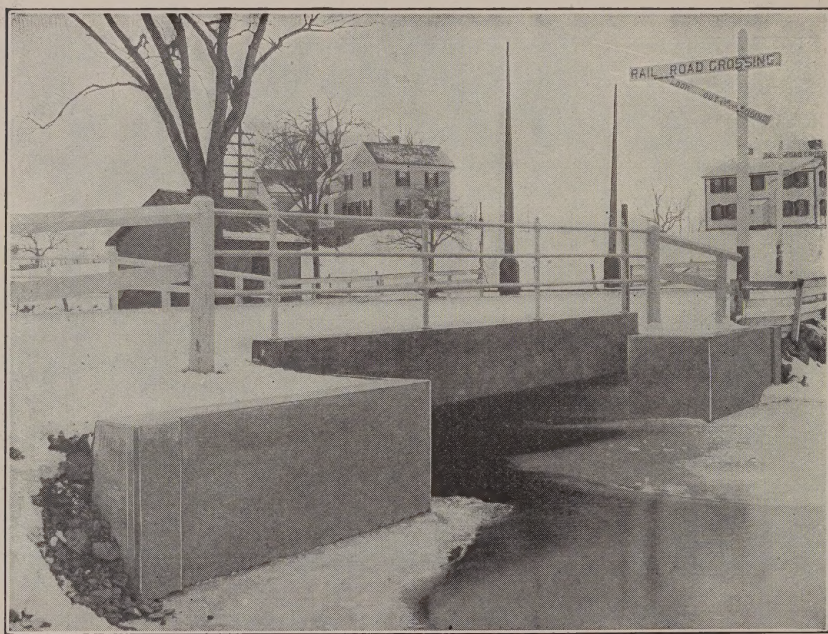
ARCH IN PHILLIPS PARK, AURORA, ILL.

near the back of the wall. These vertical rods must be imbedded in the base as shown. In this set of vertical rods every fifth rod should extend from the bottom to the top of the wall, these rods being 17 inches apart. Then midway between each pair of these long rods a shorter rod extends from the bottom of the wall $\frac{2}{3}$ of the way to the top, making the rods in the middle third of the height $8\frac{1}{2}$ inches apart. In the lower third of the height there are in addition to the rods mentioned short rods running from the base up $\frac{1}{3}$ of the height of the wall, thus making the rods in this lower third $4\frac{1}{4}$ inches c. to c.

Although $\frac{5}{8}$ -inch round rods are shown in the figure, other bars having the same cross sectional area can be used instead.

PROPORTIONS OF CONCRETE.

For gravity walls similar to those described in this chapter for the body of the wall and for the body of the coping the concrete should be mixed 1 part "ATLAS" Portland Cement, 3 parts sand and 6 parts broken stone or gravel. For the upper and front surfaces of the coping a 2-inch veneer of mortar mixed 1 part "ATLAS" Portland Cement and 2 parts sand may be used, built on a part of the coping at the same time that the concrete is placed. For a gravity wall having a height of more than 12 feet "one-man" stones may be



BEAM BRIDGE, SUDBURY, MASS.

imbedded in the concrete as indicated in Chapter I under the head of Rubble Concrete.

For reinforced concrete walls similar to those described in this chapter concrete should be mixed 1 part "ATLAS" Portland Cement, $2\frac{1}{2}$ parts sand and 5 parts broken stone or gravel.

In depositing the concrete against the forms, care must be taken to prevent the larger stones from collecting in pockets against the forms and thus making voids which will show when the forms are removed.

EXPANSION JOINTS.

When concrete is subjected to changes in temperature it will expand or contract. Therefore, in long retaining walls vertical cracks will form in the concrete unless the wall is either reinforced with steel or vertical joints are made at frequent intervals. For plain concrete walls vertical joints should be left at intervals not exceeding 30 feet; these joints allowing the sections of concrete to expand or contract without forming unsightly cracks in the face of the wall. While 30 feet is the maximum distance between expansion joints in plain concrete walls, 20 feet is the proper distance, and walls provided with joints 20 feet apart will not crack. Frequently these joints are run straight through the wall from front to back. It is better, however, to have the two adjacent sections of the wall tongued-and-grooved or V-shaped in plan.

DRAINAGE.

Unless provision is made for removing the water, it will in most cases collect behind the retaining wall and considerably increase the pressure on the back of the wall. With clayey soils or other material of similar nature, some provision must be made for removing this water by drainage. If the wall is short, a broken stone drain laid lengthwise behind the wall and properly graded so that the water will flow along the back and then away from the wall will serve every purpose. In the case of long walls, drainage holes must be placed through the wall so that the water may pass from the back to the front where it can be drained off. These drainage holes can be made by placing cement or clay tile pipes 3 or 4 inches in diameter in the concrete, sloping downward toward the front of the wall. Wooden forms of 1-inch planks can be used to make a square hole, but the planks are hard to remove after concreting. The outlet in the front face should be 6 inches above the surface of the ground in front of the wall. Two or three barrow loads of cobble stones and gravel should be placed at the upper end where the pipe pierces the back surface of the wall.

In very wet soils loose stones 10 to 15 inches in thickness should be piled up against the back of the wall from the bottom to within 2 feet of the top. This arrangement together with the weep holes just described will afford perfect drainage even in very wet material.

Weep holes should be placed from 10 to 20 feet apart lengthwise of the wall, depending on the nature of the soil. They should be placed 10 feet apart in wet ground.

MISCELLANEOUS.

Reinforced concrete fence posts are better than wooden ones because they will not decay, are more uniform in size and shape, and in the long run are cheaper. Fence posts of wood are cheaper in first cost than those made of concrete, but ordinary wooden posts decay in a comparatively short time while concrete construction lasts indefinitely. Cast iron posts last very well, but their cost prohibits their use except in a few cases. Concrete posts properly reinforced with steel rods possess the necessary strength and durability and at the same time may be obtained in any locality at a reasonable cost.



For fences adjoining streets in towns the posts should be from 5 to 6 feet in length with ends the same size as for farm posts. These posts carry wire

fences or wooden fences. If a wooden fence is supported by concrete posts the street side of the posts should be set vertical, the lower wooden stringer of the fence being bolted to the front vertical face of the post and the upper stringer bolted on top of the post.

A form for making an individual post is shown in Fig. 62 and consists of a base board $1\frac{1}{2}$ inches thick and 12 inches wide. Upon this are set two beveled pieces of 2-inch lumber 6 inches wide at one end and 4 inches wide at the other. The two side boards, connected with 2 or 3 cross braces on top, are set against, but not nailed to, the two small strips, the latter being nailed to the base board. The blocks at the ends are nailed in place.

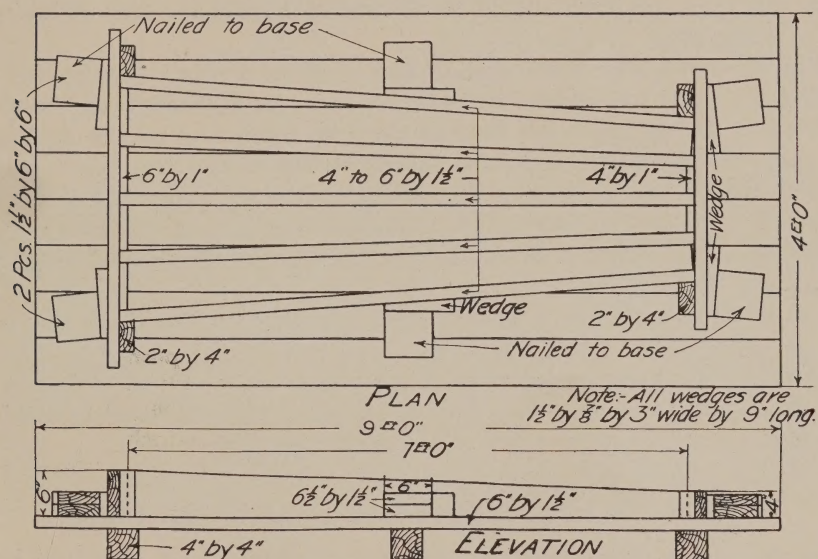


FIG. 63.—MULTIPLE FORM FOR CONCRETE FENCE POSTS.

Short pieces of $\frac{1}{2}$ -inch greased round rods should be placed through the side boards before the concrete is placed in the forms and allowed to remain four or five hours till the concrete is hardened enough so that they can be pulled out. The fence wires can be run through these holes or can be run in front of the post and tied to the same with No. 12 or 14 galvanized wire. These holes for fence wires do not decrease the strength of the post and afford a better method of attachment than staples placed in the front surface of the post. If staples are used they must be galvanized.

With the form in place, concrete, made one part "ATLAS" Portland Cement, two parts clean coarse sand, and four parts broken stone or screened gravel of about one inch diameter particles, should be placed in the form and tamped to a thickness of one inch. Then two pieces of wire about $3/16$ inch in diameter and $6\frac{1}{2}$ feet long are placed on the layer of concrete, each one inch from the side forms. Another layer of concrete must then be tamped on the first layer until the concrete is within one inch of the top edge of the side forms and two more wires like the first ones then laid and the forms filled with concrete. After the concrete is tamped and smoothed off on the upper surface, the post is set aside and allowed to lie ten or twelve hours before the side forms are removed. The base board must be left in place ten days during which time the post must be sprinkled daily and must not be disturbed. After this time the posts should be allowed to harden for four weeks more before being used.

Fig. 63 shows a mold for casting four posts at a time. The boards separating the posts are slipped in between cleats at each end and are either screwed to the end pieces or held in place by tightening up the wedges at the ends. Wedges bearing against blocks nailed to the base board prevent the side boards from spreading. Staples pressed in the upper face of the concrete before the concrete sets afford an easy connection for the fence wires.

Forms should be made of dressed lumber and should be oiled or greased with soft soap before using.

Fence posts such as here described should cost from thirty to fifty cents each.

Corner posts must be larger than the side posts, 10 by 10 inches at the base and 10 by 10 inches at the top, and 9 feet long being good dimensions. Use four $3/8$ -inch round rods for reinforcement of $3/16$ -inch.

CONCRETE FENCE POSTS AT DELLWOOD PARK.

In Fig. 64 are shown some concrete fence posts around Dellwood Park, four miles from Joliet, Ill. This fence* encloses a tract of land approximately 1,320 feet wide by 2,200 feet long and has 1,500 concrete posts varying in length from 7 to 9 feet. At the top the posts are 4 inches square and at the bottom they are 4 by 6 inches in cross section. The concrete was made one part "ATLAS" Portland Cement and one part stone screenings passing a $1/4$ -inch screen. The reinforcement consists of four rods, one in each corner.

The forms used were similar to the single form shown in Fig. 62 and were left on the posts twenty-four hours, the side boards being removed after this period. The posts were then left for an additional twenty-four hours lying

*Engineering Record, Vol. 55, March 23, 1907, page 377.

on the base boards after which the bases together with the post were moved to a platform where they remained a week. They were then laid out to harden till used, being kept wet for the first three weeks after they were made. Two men, each paid \$2 per day, could make about forty posts in one day. The cement cost \$2 per barrel, the reinforcement $3\frac{1}{2}$ cents per pound and the screenings .75 cents per cubic yard. The posts, 9 feet long, cost 65 cents each, a rather high cost because of the design and the richness of the proportions. Posts at angles of the fence were heavier than the others and were braced.

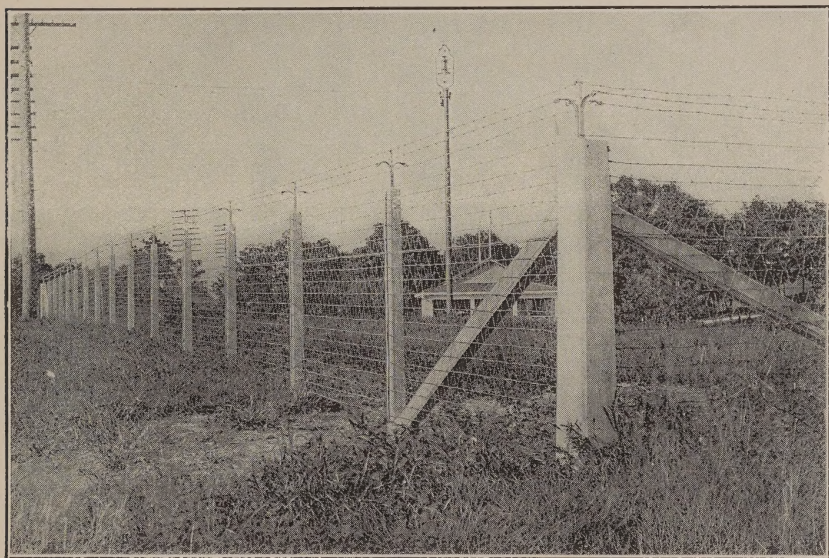


FIG. 64.—CONCRETE POSTS AT DELLWOOD PARK, JOLIET, ILL.

HITCHING POSTS.

Concrete hitching posts without reinforcement do not have sufficient strength. They must be reinforced with a $\frac{3}{8}$ -inch diameter rod imbedded in each corner. Hitching posts should be set at least $2\frac{1}{2}$ feet in the ground if they are surrounded by a concrete sidewalk. If set in earth without the surrounding walk they should be placed 3 feet in the ground. The outer surface must be at least 6 inches, or still better, 8 inches from the edge of the curb.

Posts similar to that shown at the left side of Fig. 65 are made in the same

manner as fence posts except that there is a 2-inch ring attached to a staple in the top.

The post shown in the right half of Fig. 65 is neat but is more difficult to make than the plain post. The depressed surfaces on the sides are one-half inch deep and are best formed by nailing one-half-inch wooden pieces to the inside of the forms. Tamp the concrete into the corners of the molds well and after the forms are removed give the surfaces of the posts a coating of cement mixed with water, applied with a brush.

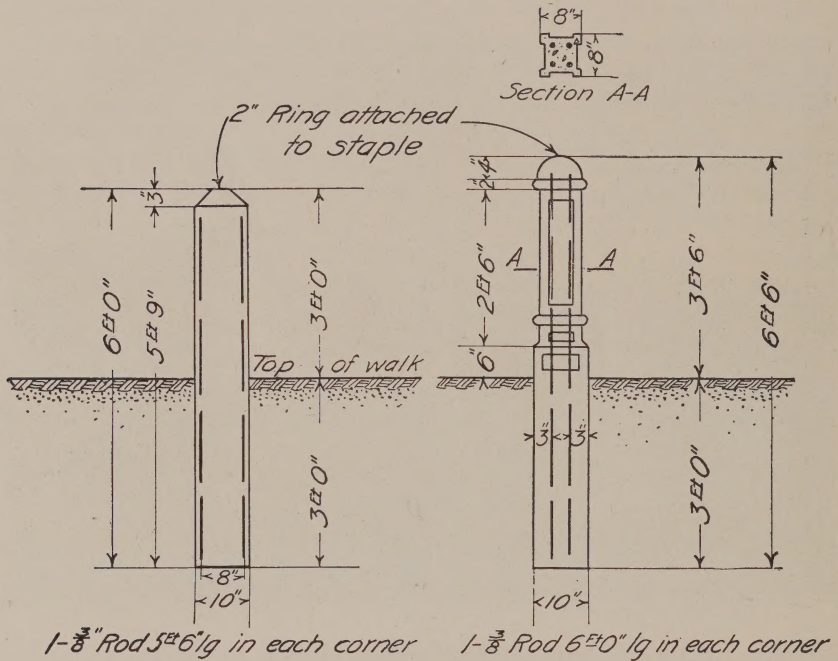


FIG. 65.—CONCRETE HITCHING POSTS.

LAMP POSTS.

Concrete is being used for lamp posts to support electric lights in parks and other similar places. These posts are usually about 20 to 24 feet in length and are set 5 or 6 feet into the ground. They should be 6 or 8 inches in diameter at the bottom and 4 or 5 inches at the top, the larger diameters being required for the highest posts. A piece of 1-inch gas pipe is placed in the center of the post throughout its length to carry the wires from the lamp to the bottom of the post where the wires then connect with the underground

electric system. The lamp can be set directly on top of the post or it can be suspended from the outer end of a curved pipe which is connected to the pipe passing down through the post. The methods of construction are similar to those used in making fence posts.

One rod one-half inch in diameter in each corner of a square post is sufficient for reinforcement. A square post with beveled edges is simpler to make than a round post, but is not quite so neat in appearance.



BRIDGE AND DRINKING FOUNTAIN, LINCOLN PARK, CHICAGO, ILL

DRINKING FOUNTAINS.

Drinking fountains of concrete are giving good satisfaction in parks even where the climate is severe. These fountains are generally made with a circular base about 3 feet in diameter and a circular stem and bowl on top; the stem gradually diminishing in diameter from the base and then enlarging into the bowl which is from $3\frac{1}{2}$ to 4 feet in diameter.

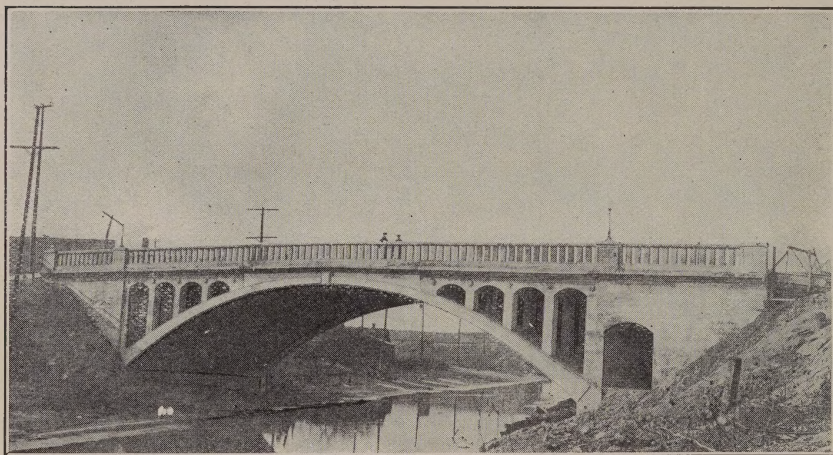
Reinforcement must be used in fountains to give them sufficient strength to withstand shocks. Wire mesh of any kind bent to shape and imbedded in the concrete is all that is necessary.

The concrete must be mixed quite wet, about the consistency of thick cream and in the proportions of 1 part "ATLAS" Portland Cement, $1\frac{1}{2}$ parts

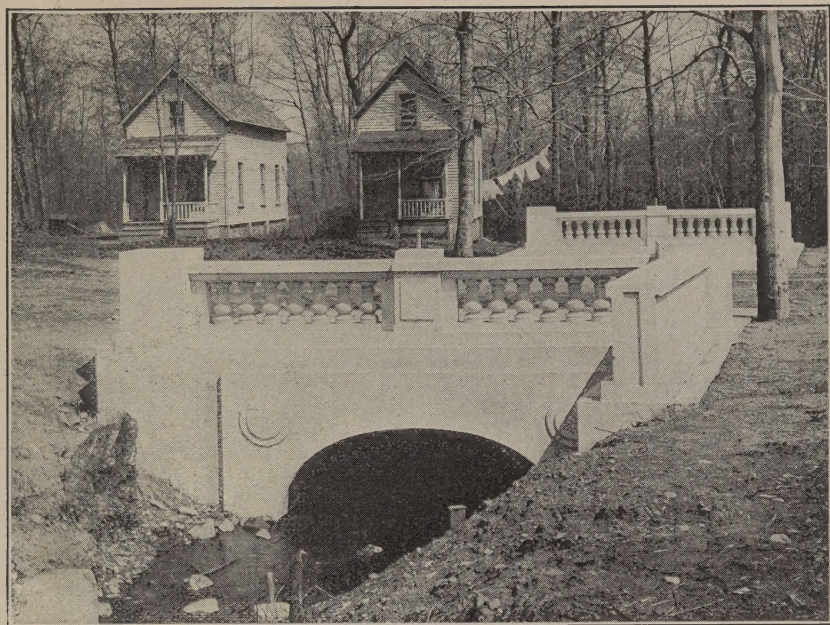
clean, coarse sand, and 3 parts broken stone or screened gravel of about 1 inch diameter.

The bowl must be cast at one operation and as quickly as possible so that it will be water tight.

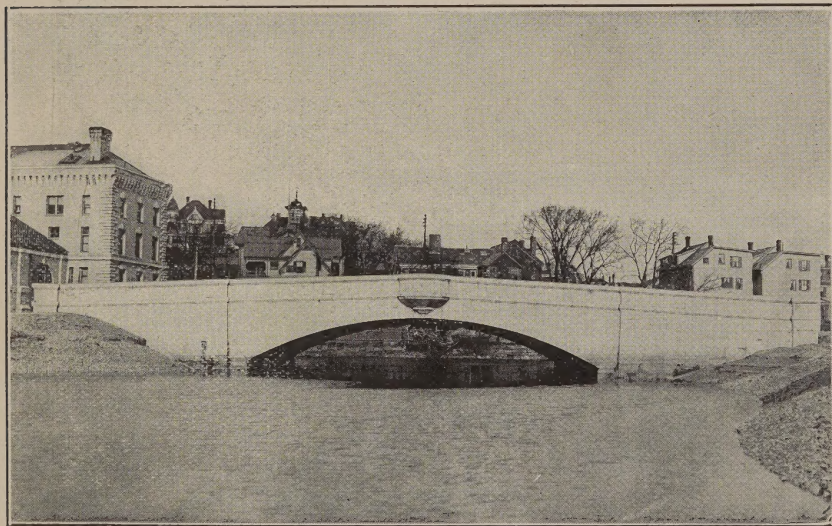
Good drinking fountains of this kind have been built for \$12 with \$5 for the setting.



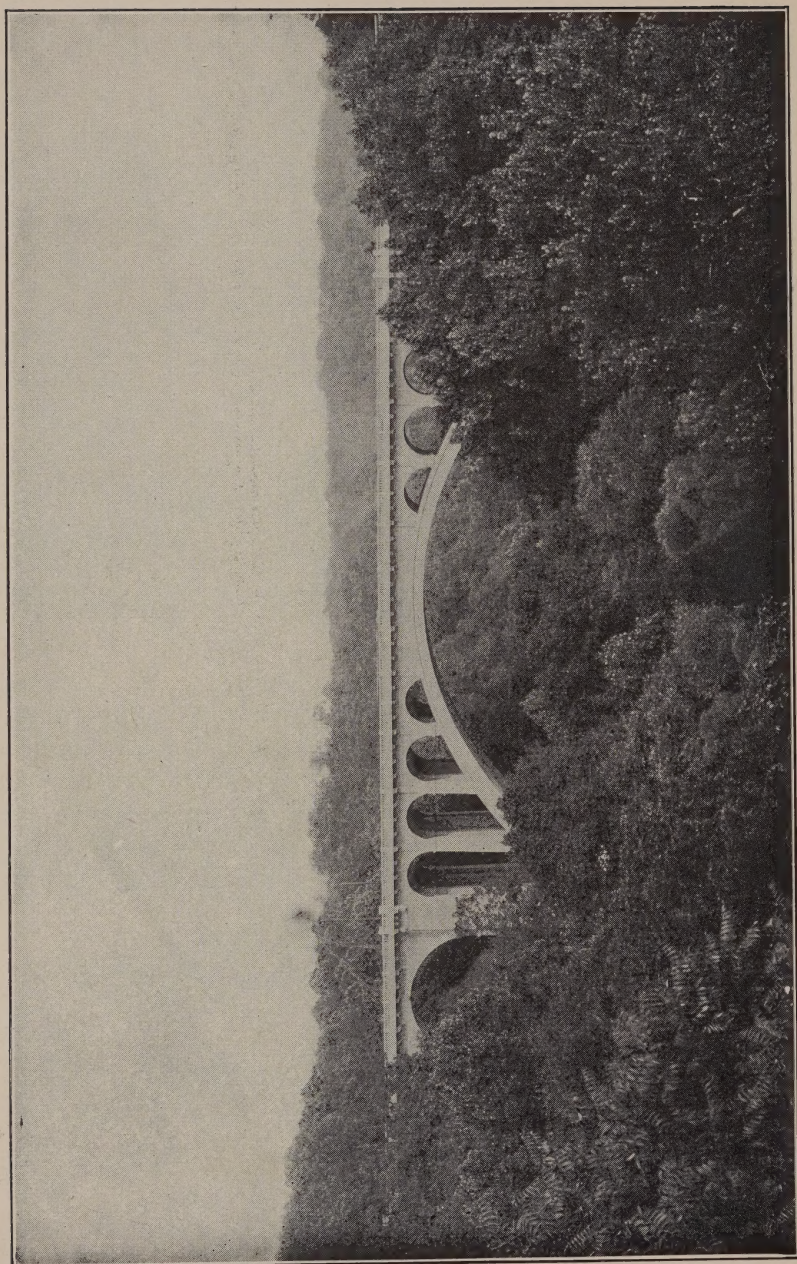
BRIDGE WITH OPEN SPANDRELS, CHICAGO, ILL.



BRIDGE AT HAWORTH, N. J.



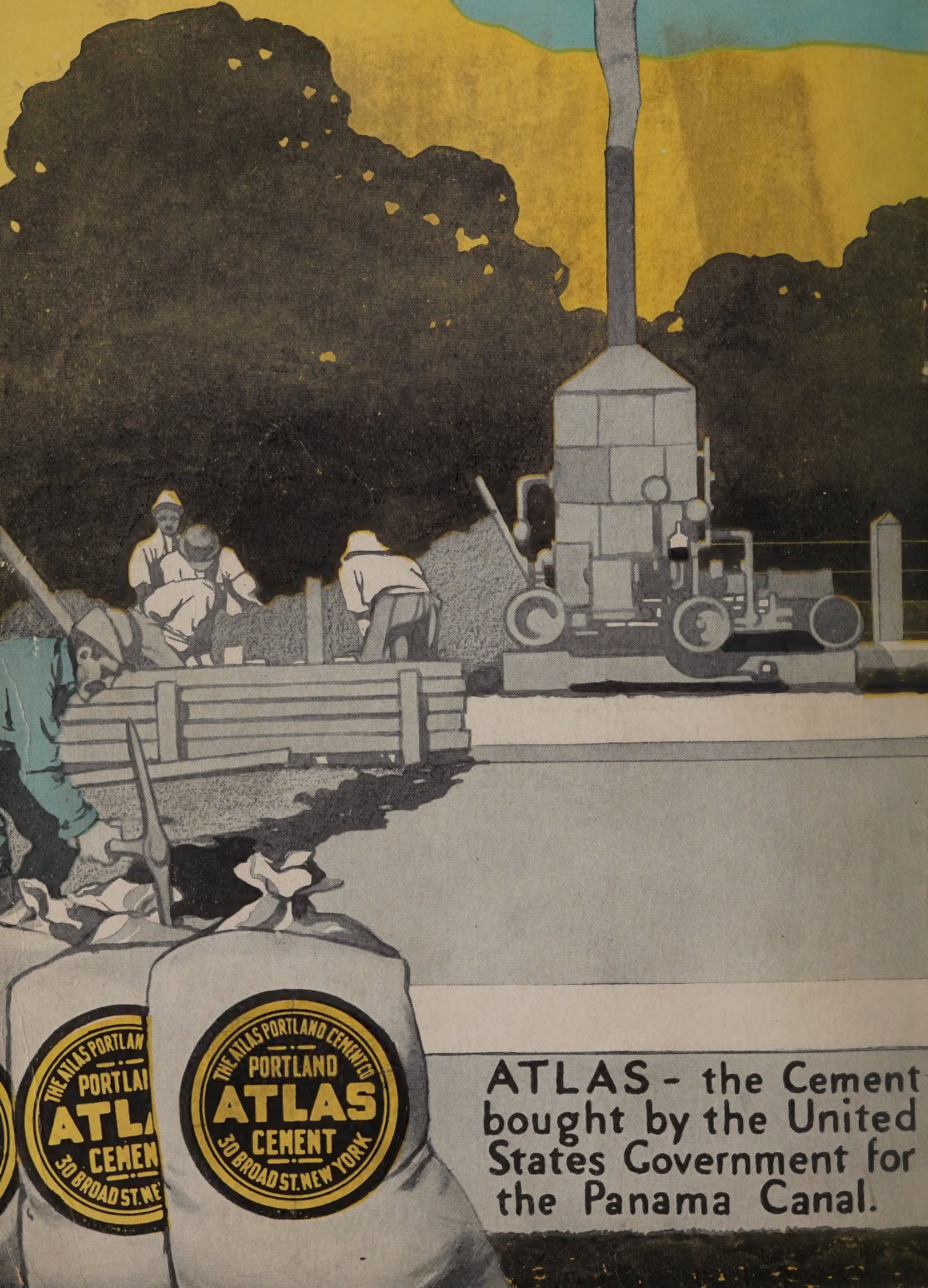
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